THE

Anatomical

EXERCISES of

Dr. *WILLIAM HARVEY*,

Professor of PHYSICK,

AND

Physician to King *CHARLES* the First;

Concerning the motion of the *HEART* and *BLOOD*.

WITH

The Preface of *ZACHARIAH WOOD*, Physician of *ROTERDAM*.

To which is added,

Dr. *JAMES* de *BACK*, his Discourse of the *Heart*, Physician in Ordinary to the Town of *ROTERDAM*.

LONDON,
Printed for *Richard Lowndes* at the *White Lion* in *Duck Lane*, and *Math. Gilliflower*, at the *Sun* in *Westminster-Hall*, 1673.

To the moſt Illuſtrious and Invincible Monarch *CHARLS* King of Great *Britain*, *France*, and *Ireland*, Defender of the Faith.

Moſt Gracious King,

He Heart *of creatures is the foundation of life, the Prince of all, the Sun of their Microcoſm, on which all vegetation does depend, from whence all vigor and ſtrength does flow. Likewiſe the King is the foundation of his Kingdoms, and the Sun of his Microcoſm, the Heart of his Commonwealth, from whence all power and mercy proceeds. I was ſo bold to offer to your Majeſty thoſe things which are written concerning the* Heart, *ſo much the rather, becauſe (according to the cuſtom of this age) all things humane are according to the pattern of man, and*

moſt things in a King according to that of the Heart; *Therefore the knowledge of his own* Heart *cannot be unprofitable to a King, as being a divine reſemblance of his actions (ſo us'd they ſmall things with great to compare,) You may at leaſt, beſt of Kings, being plac'd in the top of humane things, at the ſame time contemplate the Principle of Mans Body, and the Image of your Kingly Power. I therefore moſt humbly entreat, moſt gracious King, accept, according to your accuſtom'd bounty and clemency, theſe new things concerning the* Heart, *who are the new light of this age, and indeed the whole* Heart *of it, a Prince abounding in vertue and grace, to whom we acknowledge our thanks to be due, for any good that* England *receives, or any pleaſure that our life enjoyes:*

Your Sacred Majeſties moſt
devoted Servant,

WILLIAM HARVEY.

To the moſt Excellent and moſt Ornate man *D. Argent*, Preſident of the College of Phyſicians in *London*, his ſingular Friend, and the reſt of the Doctors and Phyſicians his moſt loving Collegs.

S. P. D.

I *Did open many times before, worthy Mr. Doctor, my opinion concerning the motion and uſe of the* heart, *and Circulation of the* blood *new in my lectures; but being confirm'd by ocular demonſtration for nine years and more in your ſight, evidenced by reaſons, and arguments, freed from the objections of the moſt learned and skilfull Anatomiſts, deſired by ſome, and moſt earneſtly required by others, we have at laſt ſet it out to open view in this little Book; which, unleſs it were paſs'd through your hands,*

hands, I could hardly hope that it would come abroad entire and safe, since I can call most of you, being worthy of credit, as witnesses of those observations from which I gather truth, or confute error, who saw many of my Dissections, and in the ocular demonstrations of these things which I here assert to the senses, were us'd to stand by and assist me. And since this only Book does affirm the blood to pass forth and return through unwonted tracts, contrary to the received way, through so many ages of years insisted upon, and evidenced by innumerable, and those most famous and learned men, I was greatly afraid to suffer this little Book, otherwayes perfect some years ago, either to come abroad, or go beyond Sea, lest it might seem an action too full of arrogancy, if I had not first propounded it to you, confirm'd it by ocular testimony, answer'd your doubts and objections, and gotten the Presidents verdict in my favour; yet I was perswaded if I could maintain what I proposed in the presence of you and our College, having been famous by so many, and so great men, I needed so much the less to be afraid of others, and that only comfort, which for the love of the truth you did grant me, might likewise be hoped for from all who were Philosophers of the same nature. For true Philosophers, who are perfectly in love with truth and wisdom, never find themselves so wise, or full of wisdom, or so abundantly satisfied in their own knowledge, but that they give place to truth whensoever, or from whosoever it comes. Nor are they so narrow spirited to believe that ever any art or science was so absolutely and perfectly taught in all points, that there is nothing remaining to the industry and diligence of others, since very many pro-

fess

fess that the greatest part of those things which we do know, is the least of the things which we know not. Neither do Philosophers suffer themselves to be addicted to the slavery of any mans precepts, but that they give credit to their own eyes; nor do they so swear Allegiance to Mistris Antiquity, as openly to leave, or in the sight of all to desert their friend Truth. For as they think them credulous and idle people, who at first sight do receive and believe all things, so do they take them for stupid and senseless, that will not see things manifest to the sense, nor acknowledge the light at mid-day; and do teach as well to decline the records of the Scepticks, as the follies of the rabble, or the fables of Poets. Likewise, all studious, good and honest men, do never suffer their mind so to be overwhelm'd with the passions of indignation and envy, but that they will patiently hear what shall be spoken in behalf of the truth, or understand any thing which is truly demonstrated to them; nor do they think it base to change their opinion, if truth and open demonstration so perswade them, and not think it shamefull to desert their errors, though they be never so ancient, seeing they very well know that all men may erre, and many things are found out by chance, which any one may learn of another, an old man of a child, or an understanding man of a fool.

But my loving Collegs, I had no desire in this Treatise to make a great volume, and to ostentate my memory, and labours, and my readings, in rehearsing, tossing the works, names, and opinions of the Authors and writers of Anatomy, both because I do not profess to learn and teach Anatomy from the axioms of Philosophers, but from Dissections, and

from

from the fabrick of Nature. As likewise that I do not endeavour, nor think it fit, to defraud any of the ancients of the honour due to them, nor provoke any of the moderns; nor do I think it seemly to contest and strive with those that have been excellent in Anatomy, and were my teachers. Moreover I would not willingly lay an aspersion of falshood upon any that is desirous of the truth, nor blemish any man by accusing him of an error; but I follow the truth only, and have bestowed both my pains and charges to that purpose, that I might bring forth something which might be both acceptable to good men, agreeable to learned men, and profitable to literature. Farewell most excellent Doctors, and favour your Anatomist,

WILLIAM HARVEY.

THE

The Preface of *Zachary Wood*, Physician at *Roterdam*, upon the Anatomical Exercise of Doctor *William Harvey*.

IT is a memorable Story which is related by one *Aventine* a *Boian* Writer, That *Bonifacius* a certain Bishop of *Ments*, hearing *Virgilius* a Bishop of *Salesburg* in a Sermon which he made before the people of those times, make mention of those men whose footsteps tread opposite to ours, was so much incensed, that he did not stick to accuse *Virgil* of Blasphemy, as that having spoke of the Antipodes, he did seem plainly to aim at another Christ; and having related the business to *Utilio* King of the *Boii*, he procured the Letters of Pope *Zachary* to *Utilio*, and so *Virgil* was both condemned by the Kings and the Popes Verdict. There is such another Story related of *Democritus*, This *Democritus* being a diligent searcher of the works of Nature, whilst he was continually busied in cutting up of creatures, he was thought mad by the *Abderitans*, who pitying the Mans condition, called *Hippocrates* that he

might give him Physick, and restore him to his lost wits; being desired, he came in all hast, and there he found *Democritus* cutting up of creatures, with which sight being marvellously taken, he avouch'd, That all the *Abderitans* were mad, and not a wise man but only *Democritus* amongst them. Now many men are like the *Abderitans*, there are now many *Bonifaces* and *Utilios* who do traduce the new inventions of those, who, as it were by the great inspiration of God, have bestowed all their studies upon the search and knowledge of things, as unprofitable, and the force of a custom once setled is able to effect so much, that no man in any barbarous place did ever seem to usurp more unlicensed power. Doctor *William Harvey*, Kings Physician, and professor of Anatomy in the Colledg of Physicians in *London*, has set out a new and unheard-of opinion concerning the motion of the heart, and circulation of the blood, which is briefly thus, First the ear of the heart contracts it self, in that contraction it thrusts out the blood contain'd in it into the ventricle of the heart, which being fill'd, the heart is dilated, and straightwayes it contracts the ventricles and makes a pulsation, by which pulsation it thrusts forth the blood thrown into it into the arteries out of the left ventricle, and out of the right into the lungs through the *vena arteriosa*, from whence immediately it is snatched into the left ventricle through the *arteria venosa*, and by it driven out into the *Aorta*, and so afterwards into the whole body through the arteries; the blood so driven out into the habit of the body, passes from the arteries again into the veins, and returns into the *vena cava*, and from

from it into the right ear of the heart, and then into the right ventricle, and ſo afterwards it paſſes through the ſame circle as before, and ſo continually, from whence he calls that motion of the blood Circulation. Truly a bold man indeed,

O diſturber of the quiet of Phyſicians!

O ſeditious Citizen of the Phyſical Common-Wealth!

Who firſt of all durſt oppoſe an opinion confirm'd for ſo many ages by the conſent of all, and delivered up in the monuments of ſo many Phyſicians, and as it were given from hand to hand to poſterity, as if no man had been wiſe in all ages paſt. Indeed they do very decently who worſhip antiquity as becomes them; but it is a thing unworthy in wiſe men who do aſcribe wiſdom to antiquity, with no little wrong to poſterity, as if it were not common to all times, and to all men; for as *Lactantius* in the 2 *Book* of his Divine Conſtitutions, 8 *Chap.* Becauſe they had the precedency before us in time, they had not the precedency before us in wiſdom, which, if it be given to all alike, it cannot be foreſtall'd by thoſe that go before, but is untouchable as the light and clearneſs of the Sun; for as the Sun is the light of the eyes, ſo wiſdom is the light of mans heart. And truly, if thoſe by whoſe benefit and ſtudy we have the invention and conſtitution of Phyſick, had been of the ſame mind with theſe reprovers, & had thought nothing worthy publiſhing but what had been approved in the account and judgement of their Anceſtors, ſuch refin'd and elaborate arts had never come to light; but the ancients knowing certainly that they had found out many things, ſome things

likewiſe they had not perfectly enquir'd into, and that ſome were to them perfectly unknown, and believing that the way of ſearching out the truth was not ſtopp'd, but guarded for them by the example and diligence of antiquity, they did with ready minds endeavour that they might either go on in the ſame path with them, or paſs beyond them in a further ſearch. They did as it were advance the banner towards the ſearch of hidden cauſes, and went before us in example, that we might follow them; for this is the liberty of wiſdom, that being oblig'd to none, it's under its own command and juriſdiction; in her Common-wealth it's permitted to abrogate, derogate, and ſearch without prejudice to any, which liberty if we take away we ſhall alwayes continue in the cradle of arts, nor will there be any thing from whence we hope for their increaſe, or for any thing better than has been publiſhed; for which cauſe we do require, that juſtice and courteſie in judgement may be given of us which we afford to others; if the ſame thing be alwayes to be thought and ſpoken, it will not be lawfull to find out any new thing, nor muſt we take hold of what the very thing and reaſon it ſelf dictates to us; 'tis ridiculous therefore to tread in the ſteps of the Ancients, and alwayes to follow them. Nor does *Galen* approve of any Anatomical Comment, unleſs it contain ſome new thing. It is a dull wit which is ſatisfied with that which others have invented, ſeeing all humane things are ſubjected to the ſharpneſs of the mind. The treaſures of Nature are immenſe, and her wiſdom inexplicable, ſo that thoſe things which daily come abroad do prepare

a way

away to ſearch out thoſe things which follow; for truth is drown'd in a deeper well than that it ſhould be drawn out from thence in a few ages. It is true that *Aruns* ſaid, That we were not taught all things at one time by *Jupiter*, but that a great many things do remain hid, of which ſome he will grant to us afterwards. *Galen* ſays, that the cunning of Nature in the fabrick of mans body is ſo great, that though great men have diligently and conſtantly ſearched after it, yet have they not found it all out.

Long age, and divers travels in times change
Have better'd it, nor all thoſe whom we range
Amongſt the Antients know what we do know,
Young men ſome things to obſervation owe.

Therefore ſince to be wiſe, that is to ſay, to ſearch after the truth, is born with all men, they take away all wiſedom from themſelves who without any judgement approve of their forefathers inventions, and are by them lead like Cattel, and do brag raſhly, that they ſee thoſe things in them which they do not ſee. The Comedy which uſes to be acted by the Players looks much like this. By a certain cheating Taylor, there was a piece of excellent cloath deſcrib'd to an idle and ſimple Braggadochio, but of ſuch a colour, that it could not be ſeen by baſe begotten people or baſtards; therefore this Braggadochio deſirous to buy, requires a ſight of the cloath; the Cheat preſently as a huge piece having many els in it, brings it out in both his hands, as the Merchants uſe to do here, turns down the folds, wonders at the fair-

ness of it, praises it, and commends it to his buyer; this vain Braggadochio was presently touched with a suspition that his Mother had played the Whore, yet shame hinder'd him to confess, therefore he sayes that he sees, and wonders at the cloath which he did not see, and indeed was not at all, and buyes it, and commands him to make him a Suit of it; then the Taylor began to be very merry, and jovial, divides the cloath, imitates wonderfully the noyse of cutting it, and makes him up a garment of this fine unseen and invisible cloath, receives his money, and gives it him. Believe me this fable in incredulous men without judgement is a true history, and no fable; they believe, and why should not they give credit to Physitians approv'd by the judgements of so many ages? yet they do not see, nor can they see, that which is not; yet left they should seem blockheads, they praise, admire, and buy; not only with expence of money, whose damage is tolerable, but even with the loss of time and life, the damage of which can be redeem'd by no money. Truly, that I may speak the truth, we must give less credit to authority, and we must restrain our assent, and besides authority look after reason too by the example and authority even of antient Philosophers and Physitians; and first of all by the example of that divine *Plato*, whom *Cicero* so much esteems, that he does not stick sometimes to call him the *Homer* of Philosophers, sometimes a God; in whose Book, O fortunate Sir (says *Socrates* to *Polus* a young man who in his discourse concerning a blessed life produc'd testimony) you endeavour to convince me as Orators

do,

do, and as they do in tryals where they think that they foil one another when they bring many and famous Witneſſes for their Cauſe, and the Defendant brings none, or ſome one, ſince this proof is of no conſequence towards the truth; for many times a man is unjuſtly oppreſs'd, becauſe of the multitude of witneſſes, and of thoſe too who ſeem to be of ſome worth and account: and ſo likewiſe in his *Charmides*. Nor is it to be conſidered who ſpeaks, but whether truth be ſpoken or no; theſe and the like are every where in *Plato*. But let us hearken to *Ariſtotle* in this point, treading directly in his Maſters footſteps, who, as he did not ſpare any of the antient Philoſophers no more did he *Socrates* and his Maſter *Plato*; for being to diſpute againſt the Ideas, he ſays, Though it be a hard queſtion, becauſe that thoſe who brought in the Ideas are our friends, yet it is neceſſary for the retaining of the truth to take off their opinions, eſpecially they being Philoſophers; for albeit they be both gallant men, yet it is a gallanter thing to honour the truth beyond them. Shall not we ſay that it is here clearly ſet down in what eſteem the authority of the moſt grave Philoſophers is to be had? when *Socrates* cryes out, That *Hippocrates* and others witneſſes evidences; and *Ariſtotle* cries out, That *Socrates* and *Platos* evidences, are not ſo much to be weighed and eſteemed as thoſe of truth and reaſon; eſpecially ſince *Cicero*, a man of divine quickneſs of wit, and ſingular judgement, who for the many prayſes both of *Plato* and *Ariſtotle* may ſeem to have ſworn allegiance to them both, did not unwillingly turn to the haven of the Stoicks, leaving the Acade-

my of *Plato*, and the Lyceum of *Ariſtotle*. I do likewiſe believe that he would have paſſed over to the Cynoſarges of the *Cireneans*, or the Gardens of the *Epicureans*, and the Schools of other Philoſophers, with the ſame freedom, if he had found or judged any thing in them worthy of his knowledge; as likewiſe calling back all learners from their credulous ſuperſtitions, by name he admoniſhes them that the evidences of Authority are not to be ſo much to be ſought for as the evidences of reaſon; becauſe the authority of thoſe who teach is many times prejudicial to thoſe who learn, for they leave off to try any thing by their own judgment, they account that firm which they ſee to be ſo judged by him whom they approve of. For which cauſe let us compare true principles of Phyſick, though new, with the opinions of the Antients, for here we ſhall find many things diſagreeing; let us try the Anatomical exerciſe of *Harvey*, let us ſee what that will help us: nor let us longer imitate the *Sepias*; for as thoſe who when they find that the Fiſhermen are in purſute of them throwing out ink, which they have inſtead of blood, darkning the water, hide themſelves, and do as it were ſtop and block up the Fiſhermens way; nor let us need to be ſo preſs'd and conſtrain'd by truth, light, firm and conſtant reaſon, for that troubled water will ſettle at ſome time, time will blot out the inventions of opinion, and confirm the judgments of truth. We have a very remarkable tryal of this in a very famous man, *Vopiſcus Fortunatus Plempius*, Doctor of Phyſick and Arts in the Univerſity of *Lovain*, and prime practitioner there, whoſe opinion of *Harvey* we thought

fit

fit here to set down, which he gave in his 2 *Book* concerning the foundation of Physick, *Chap.* 7. these are his words, *England* of late hath brought forth a new opinion concerning the motion of the heart, which *William Harvey* hath published in a little Book purposely set out by him; he builds his opinion upon very plausible reasons, insomuch that it is allowed by many learned men at this day, and he is call'd as by a title of honour by one of his own Countreymen, the surrounder of the little World, to distinguish him from another Englishman who first went about the greater World. This invention did not please me at first, which I did testifie both by speech and writing against it, but afterwards when I did most earnestly endeavour to refute and explode it, I was refuted and exploded my self, so much are his reasons not only perswading but forcing; but diligently did I examine it all, and in some dogs, dissected by me for that end, found it to be very true, being likewise advis'd to do this by a most famous man, *Walæus*, Professor of *Leyden*, whose candid and setled judgement I do much esteem, and in this business am much engaged to him. Here's a great change in his judgement. Hence I begin to hope for equity in others, that laying aside all hatred, and acknowledging their error, they will at last with *Plempius* begin to think well of *Harvey*. It is a sign of a malicious and wicked mind to be delighted with errour, to hate light, to follow darkness, to calumniate the industry of good men, which fault belongs only to very

very filthy and vile persons; vile we may say, not a good nature, nay, no tollerable or high disposition was ever tainted with this blemish. Search antient times, search ours, you shall not read, hear, nor see, any other than melancholly and malignant natures, which *Saturn* has blasted with his constellation, envious to others, and distrustful of themselves, prone and made apt to this vice. Do not you see that those little dogs which bark at guests, do not touch wild beasts? such men as those are worse, being only born to wound and vex people; born I say, for really they do so lean and encline to that vice, that they are never at rest but when they disturb others. If his reprovers should say, *William Harvey* has observed, and found fault with the errors of the antients, they should indeed say true but they should say much truer if they should add, *William Harvey* by his long and studious observation, and meditation of things in Anatomy, has propounded the means to take away all Thorns, Flints, and other impediments out of the way of Physick, that the journey of it might be plain, easie, quick, and streight, that not only the attainment to the truth and understanding of Physick, but also to the profit and fruit of it might be more easie. The wisdome of *Socrates* is known well enough by the Oracle of *Apollo*, amongst whose praises that was remarkable, and the chief, to refer the ends of liberal arts to the fruit of mans life, that men being instructed by these arts, might more easily and more readily advise concerning the transacting of business, and more readily

dily execute and perform them; our *Harvey* had this end before his eyes, he open'd only the truth and fruit of the art of Phyſick; for he ſaw that there was a great gleaning left, that many things remain'd in the wild acres of Nature hitherto untouch'd and unpaſſageable, into the poſſeſſion of which, as to an empty place, wiſe men might come; but *Harvey* did not truſt other mens writings, but his own faithful eyes, the trueſt reporters of Anatomy, becauſe Anatomy is better gain'd by ocular inſpection than by long reading, and profound meditation. None is forc'd to ſwear allegiance to a Maſter, whom nevertheleſs we likewiſe truſt after experience. *Eupompus* a ſingular good Limner being asked whom of all thoſe that went before him he chiefly followed, it is reported that he ſaid, ſhowing a multitude of men, Nature her ſelf was to be imitated, not the Artificer. This ſame *Harvey* perform'd ſo much, and has arrived ſo far by ſearching of Nature, that he, juſt like *Archimedes*, when he found out that the Coronet of Gold was mixt with Braſs, he cryed aloud, I have found it, I have found it. This is a true and hallowed Law of antient Philoſophy, *Plato*'s my friend, and *Socrates* too, but Truth is more my friend than they both. Wherefore let *ipſe dixit* never be held here, let no excellent mans Authority be brought for an Argument, let no opinion have a prerogative, but let the better bear it away. Laſtly, whilſt others endeavour to defend Antiquity, let us, together with *Harvey*, plead Truths cauſe; Let us approve thoſe things which are agreeable to truth, and reject thoſe things which are contrary to it; weighing and eſteeming the inventions

ventions of antiquity not in the ſcale of Antiquity, but in the ſcale of Truth. To this purpoſe we have again ſet forth *Harveys* Anatomical Exerciſe, which in the year 1648 was ſet out at *Francfort*, very faulty by the Fault of the Printer, which the Author oft complain'd of, finding that the calumnies of his reprehenders had their beginning from thence, who not underſtanding what he ſaid, did take them ill, and endeavour'd to traduce him publickly; I ſay we have ſet it forth, and have taken a great deal of pains, that ſo much as was poſſible all things intricate, confuſed, or unperfect being taken away, that ſame exerciſe might come forth mended and reſtored, in this buſineſs having had the help of moſt learned *De Back*, our intire Colleg, whoſe judgment we do much eſteem. But that we may fold up the ſails of this our preface, let us imitate Antiquity in honoring the inventors of things. Truly, in former time the invention of Phyſick was ſo admirable, the experience of it ſo ſecret, that the Authors of it were either plainly eſteem'd Gods, as *Apollo* and his Son *Æſculapius*, or elſe they were thought worthy of Divine honour, as *Aſclepiades* whom the *Illyrians* receiving as a God, did equal in honour to *Hercules*. Truly I do not approve all that Antiquity hath done, yet truly I do praiſe their affection and judgment, as having rightly thought, and judged, no reward ſufficiently worthy to be paid to the inventors of the art of Phyſick. Therefore let *Harvey* be amongſt us in perpetual eſteem, by whoſe learning we have a way open'd to ſee ſo great a light of the Art of Phyſick, to

love

love and to imitate it. Let us freely attribute the modeſt commendation of the Son of *Syrach* concerning his own work, to *Harvey*: I watched law of all, as he that gleans ears after the Reapers, I have profited through Gods Grace, I have fill'd the Winefat; Conſider that I have not taken pains for my ſelf, but for all thoſe which love learning.

THE

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Chap.

THE

THE PROEME.

By which is Demonſtrated, that thoſe things which are already written concerning the motion and uſe of the Heart and Arteries, are not firm.

IT will be worth our while, ſeeing we are thinking of the motion, pulſe, uſe, action, and utility of the *heart* and *arteries*, firſt to unfold ſuch things as have been publiſhed by others; to take notice of thoſe things which have been commonly ſpoken, and taught, that thoſe things which have been rightly ſpoken may be confirmed, and thoſe which are falſe both by Anatomical diſſection, manifold experience, and diligent and accurate obſervation, may be mended.

Almoſt all Anatomiſts, Phyſicians, and Philoſophers to this day, do affirm with *Galen*, that the uſe of Pulſation is the ſame with that of Reſpiration, and that they differ only in one thing, that one flows from the Animal faculty, and the other from the Vital, being alike in all other things, either as touching their utility, or manner of motion. Whence they affirm, (as *Hieronym. ab Aq. p.* in his Book of Reſpiration, which

he has newly set out) Because that the pulse of the *heart* and *arteries* is not sufficient to fan, and refrigerate, that the *lungs* were made about the *heart*. Hence it appears, that whatsoever those in former times did say concerning the *Systole* and the *Diastole*, concerning the motion of the *heart* and *arteries*, they spoke it in relation to the *lungs*.

But since the motion and constitution of the *heart* is different from that of the *lungs*, and the motion of the *arteries* different from that of the breast, it is probable that divers uses and utilities should follow, and that the pulse of the *heart*, and the use of it, as likewise that of the *arteries*, should differ much from the pulse and use of the breast and *lungs*. For if pulse and respiration do serve for the same use, and that the *arteries* do receive the air into their concavities in the *Diastole*, as they commonly say, and that in their *Systole* they send out fumes through the pores of the flesh and skin; as likewise that in the space betwixt the *Systole* and *Diastole* they do contain air; and that every time they do either expell Air, or Spirits, or Fumes; what will they then answer to *Galen*? who wrote a Book, that blood was naturally contain'd in the *arteries*, and nothing but blood, that there is neither Spirits, nor Air, as from Reasons and Experiments in the same Book we may easily gather. And if in the *Diastole* the *arteries* are fill'd with Air which they take in, and that in a greater pulse there enters a greater quantity of Air; it will follow, that whilst there is a great pulse if you dip your whole body into a bath of Water or Oyl, that the pulse shall either be lessen'd, or much slower, since it is a hard thing for the Air to pass through the body of the bath which encompasses them, and get into the *arteries*, if not altogether impossible. Likewise since all the *arteries*, as well those which lye deeper,

as

as thoſe which are next to the skin, are diſtended with the ſame ſwiftneſs, how can the Air ſo freely, ſo ſwiftly, paſs through the skin, fleſh, and habit of the whole body, into the depth, as it can through the skin alone? And how ſhall the *arteries* of *Embryons* draw the Air into their concavities through their mothers belly, and the body of the womb? And how ſhall Whales, Dolphins, and great Fiſhes, and all ſorts of Fiſhes in the bottom of the Sea, take in the Air, by the ſwift pulſe in the *Syſtole* and *Diaſtole* of their *arteries*, through ſuch a great maſs of water? But to ſay that they ſup up the Air implanted in the water, and do return their fumes into it, is not unlike a fiction. And if in the *Syſtole* the *arteries* do expell their fumes out of their concavities through the pores of the fleſh and skin, why not the Spirits likewiſe, which they ſay are contain'd there too, ſince Spirits are much thinner then fumes? And if the *arteries* do receive the Air both in the *Syſtole* and the *Diaſtole*, and return it, as the *lungs* do in reſpiration, why do not they do this in inflicting of a wound when an *arterie* is cut? In the cutting of the wind-pipe by a wound it is clear, that the Air does enter and return by two contrary motions. But it is clear in the ſection of an *arterie*, that the Air is thruſt out with one continual motion, and the Air does not enter and return. If the pulſe of the *arteries* do refrigerate the parts of the body, and cool it, as the *lungs* do the *heart* it ſelf, how do they ſay that the *arteries* do carry the blood very full of vital Spirits into all the parts which do nouriſh the heat of the parts, wake it when it is aſleep, and recruit it being ſpent? and how comes it to paſs, that if you tye the *arteries*, the parts are not only numm'd, cold, and look pale, but at laſt leave off to be nouriſhed? which happens, according to *Galen*, becauſe they are alſo depriv'd of

that heat, which did flow from above out of the *heart*: Since it is clear from hence, that the *arteries* do rather carry heat to the parts, then cooling or refrigeration. Beſides, how ſhall the *Diaſtole*, both draw Spirits from the *heart* to warm the parts, and likewiſe draw cold from outwards? Further, although ſome affirm, that the *lungs*, *arteries*, and *heart* do ſerve for one and the ſame purpoſe; Yet they ſay that the *heart* is the ſtore-houſe of the Spirits, and likewiſe that the *arteries* do contain Spirits and ſend them abroad; but contrary to the opinion of *Columbus*, they do deny that the *lungs* do make any Spirits or retain them. But likewiſe theſe men affirm with *Galen* againſt *Eraſiſtratus* that blood is contain'd in the *arteries*, and not Spirits. Theſe opinions ſeem to quarrel with one another, and to refute each the other, inſomuch that all are not undeſervedly ſuſpected. It is manifeſt that the blood is contain'd in the *arteries*, and that the *arteries* alone do carry out the blood, both by the Experiment of *Galen*, as likewiſe by the cutting of an *arterie* in wounds, (which *Galen* in his Book, that blood is contain'd in the *arteries* affirms, and in very many places) that by a great and forcible profuſion the whole maſs of blood will be exhauſted in the ſpace of half an hour. The Experiment of *Galen* is thus, *Bind the Arterie at both ends with a little cord, and cutting it up in length, in the middle you ſhall find, in that place which is comprehended betwixt the two ligatures, nothing but blood, and ſo does he prove that it contains only blood.* Whence we may argue likewiſe in the ſame manner; If you find the ſame blood in the *arteries* which is in the *veins*, being bound and cut up after the ſame manner, as I have often tryed in dead men, and in other creatures, by the ſame reaſon we may likewiſe conclude, that the *arteries* do contain the ſame blood which the *veins*; and nothing

but

but the ſame blood. Some whilſt they endeavour to diſſolve this difficulty, affirming that it is *Arterial blood* and full of Spirit, they do ſilently grant that it is the function of the *arteries* to carry the blood from the *heart* into the whole body, and that the *arteries* are full of blood. (For the blood that has Spirit is no leſs blood.) Likewiſe no man does deny that the blood, as it is blood, and flowes in the *veins*, is imbued with Spirits. Albeit the blood in the *arteries* do ſwell with greater ſtore of Spirits, yet thoſe Spirits are to be thought inſeparable from the blood, as thoſe which are in the *veins*; and that Blood and Spirit make one body, as whey and butter in milk, or heat and water in warm water, by which the *arteries* are fill'd, and the diſtribution of which body from the *heart* the *arteries* do perform, and this body is nothing elſe but blood. But if they ſay that this blood is attracted out of the *heart* into the *arteries* by the *Diaſtole* of the *arteries*, then they ſeem to preſuppoſe that the *arteries* by their own diſtenſion, are fill'd with that blood, and not with the ambient Air as before; but if in the *Diaſtole*, they ſhall together receive the blood, the air, the heat, and the cold at one time, that is improbable. Further, when they do affirm that the *Diaſtole* of the *heart* and *arteries* is at one time, and ſo their *Syſtole*, one of theſe two will be inconſiſtent. For how ſhall two bodies ſo nearly joyn'd together, whilſt they are diſtended, one of them draw from the other, or when they are contracted at one time, how ſhall one receive any thing from the other? Over and above, it may be perchance impoſſible, that any body ſhould ſo attract into it ſelf, as that it ſhould be diſtended, ſeeing to be diſtended is to ſuffer, unleſs it do as a ſponge returning to its own natural conſtitution after external conſtriction. It were a hard thing to feign that any ſuch

thing could be in the *arteries*. But I believe I can eaſily demonſtrate, and have heretofore demonſtrated that the *arteries* are diſtended, becauſe they are fill'd like Satchells or baggs, not becauſe they are blown up like bladders. Yet notwithſtanding *Galens* Experiment, in his Book, that blood is contain'd in the *arteries*, is otherwiſe, after this manner. He did cut the *arterie* being laid open in length, and into the wound he thruſt a reed or a hollow pipe and ſtop'd the wound that the blood could not leap out. *So long* (ſayes he) *as the arterie is thus, all of it will beat, but ſo ſoon as with a thred you have above the arteries and pipe contracted the tunicle of the arterie with a nooſe, and ſtop'd it with heed, you ſhall not ſee the arterie beat any more above the nooſe.* I have neither tryed this Experiment of *Galens*, nor do I think it can be tryed and the body kept alive, by reaſon of the preruption of the blood out of the *arterie*, nor can the pipe cloſe the wound without a *ligature*; nor do I doubt but that the blood will ſtream further through the concavity of the pipe. Nevertheleſs *Galen* by this Experiment ſeems to prove, that the pulſifick faculty flows through the *tunicles* of the *arteries* from the *heart*, and that the *arteries* whilſt they are diſtended by the pulſifick faculty are fill'd, becauſe they are diſtended as bellows, not diſtended becauſe they are fill'd like baggs. But the contrary is manifeſt, both in cutting of an *arterie*, and in wounds: For the blood is poured out of the *arteries* with a forcible leaping, ſometimes farther, ſometimes nigher, leaping by fits, but the leaping of it is alwayes in the *Diaſtole* of the *arterie*, not in the *Syſtole*. By which it appears clearly, that the *arterie* is diſtended by the impulſion of blood. For of it ſelf it cannot by its diſtention throw the blood out ſo far, it ſhould rather attract Air into it through the wound, according to thoſe things

things which are commonly ſpoken. Nor let the thickneſs of the *arterial tunicles* coſen us in that, that the pulſifick faculty flows from the *heart* by the *tunicles* themſelves; for in ſome creatures *arteries* do differ nothing from *veins*, and in the moſt remote parts of a man, and the diſſeminations of the *arteries*, as in the brain, hand, &c. no body can diſtinguiſh an *arterie* from a *vein*, for they have both the ſame *tunicles*. Beſides in an *Aneuriſm*, which is begot by the arroſion or inciſion of an *arterie* it has the ſame pulſation with an *arterie*, and yet it has not the *tunicle* of an *arterie*. Moſt learned *Riolan* doth witneſs this with me in his ſeventh Book. Nor let any man believe, that the uſe of pulſe and reſpiration is one and the ſame, becauſe that the pulſes are greater, more frequent, and ſwifter, for the ſame cauſes as reſpiration is, to wit with running, anger, bathing, or any other thing which heats. For not only that Experiment is falſe (which *Galen* endeavours to convince) that by immoderate repletion the pulſes are greater, and breathing leſſer; but likewiſe in boys, pulſes are frequent, and reſpiration the while very ſeldome. Likewiſe in fear, care, and anxity of the mind, as alſo too in ſome feavers the pulſes are ſwift and frequent, and reſpirations more ſeldome. Theſe and the like inconveniences do follow upon the opinions which are ſet down concerning the pulſe and uſe of the *arteries*. Likewiſe thoſe things which are affirmed concerning the pulſe and uſe of the *heart* are no leſs entangled with very many and inextricable difficulties. They do commonly affirm that the *heart* is the ſtore-houſe and fountain of vital Spirit, by which it gives life to all the parts, and yet they deny that the *right ventricle* makes Spirits, but only gives nouriſhment to the *lungs*; from whence ſay they fiſhes have no *right ventricle* of the *heart*, and indeed in

thoſe which have no *lungs* it is wanting, and that the *right ventricle* of the *heart* was meerly made for the *lungs* ſake.

1. Why I beſeech you? ſince the conſtitution of both the *ventricles* is alike, their *fibers* fram'd alike, and ſo of their *tendons*, *Portals*, *veſſels*, *ears*, and both of them are found full of blood in diſſection, alike blackiſh, alike knotty: why I ſay ſhould we think that they were appointed to ſuch diverſe different uſes, ſeeing action, motion, pulſe, is the ſame in both? If the three three pointed *portals* in the entry of the right *ventricle*, be a hinderance of the return of the blood into the *vena cava*, and if thoſe three ſemilunary *portals* in the *oriſice* of the *arterioſa vena* were made to hinder the regreſs of the blood; ſince they are ſo likewiſe in the *left ventricle*, ſhall we deny that they were likewiſe made to hinder the egreſs and regreſs of the blood there?

2. And ſince they are almoſt altogether after the ſame manner, both in their form and poſition in the *left* as in the *right*, why do they ſay that here they hinder the egreſs and regreſs of the Spirits, and in the right hinder the egreſs and regreſs of the blood? this ſame *organ* does not ſeem to be fit to hinder the motion of the blood and Spirits alike.

3. And how is it probable, as *Realdus Columbus* does obſerve, that there needs ſo much blood to the nutrition of the *lungs*, ſince this veſſel, (that is to ſay) the *vena arterioſa*, is bigger then both the branches of the diſtributives deſcending into the crural *vein*?

4. And I beſeech you ſince the *lungs* are ſo near, and the veſſel is ſo great, and they in continual motion, what needs the motion of the *right ventricle*, and what is the matter that nature for the nouriſhing of the *lungs* was forc'd to joyn another *ventricle* to the *heart*?

When

When they ſay that the *left ventricle* draws matter out of the *lungs*, and the right boſome of the *heart*, to make Spirits, that is to ſay air and blood, and does likewiſe diſtribute the ſpirituous blood into the *aorta*, and that fumes are ſent back by the *Venal arterie* into the *lungs*, and the Spirits into the *aorta*, what is it that makes the ſeparation, or how comes it to paſs, that ſpirits and fumes paſs ſometimes hither ſometimes thither without permiſtion and confuſion? if the three-pointed mitre-faſhioned *portals* hinder not the return of fumes into the *lungs*, how ſhall they hinder the return of air? And how ſhall the half-moon *portals* hinder the regreſs of the ſpirits from the *aorta*, the *Diaſtole* of the *heart* purſuing? and by what manner of way do they ſay that the ſpirituous blood is diſtributed through the *Venal arterie* into the *lungs* out of the *left ventricle*, and that the three-pointed doors do not hinder? ſeeing they affirm that the air does enter through the ſame veſſel out of the *lungs* into the *left ventricle*, to the regreſs of which they would have theſe three-pointed doors to be a hinderance. Good God how ſhall the three-pointed doors hinder the regreſs of air and not of blood? Further they having deſtined the *vena arterioſa* being a large veſſel, made with the *tunicle* of an *arterie*, for one only and a private uſe, that is to ſay to nouriſh the *lungs*, Why do they affirm that the *Venal arterie* being ſcarce ſo big, having the *tunicle* of a *vein* ſoft and looſe, to be made for more uſes, to wit three or four? For they will have the air paſs through it, out of the *lungs* into the *left ventricle*, and they will have the fumes likewiſe to return through it out of the *heart* into the *lungs*, they will have a part of the ſpirituous blood to be diſtributed by it, for the refreſhing of them: They will have theſe to ſend fumes from the *heart*, and the other to ſend air to the *heart* by

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the ſame pipe; when notwithſtanding nature did not uſe to frame one veſſel, and one way, for ſuch contrary motions and uſes, nor is it ever ſeen to be ſo.

If they do affirm that fumes and air do go and return by this way, as through the tranſpirations or *Bronchia* of the *liver*, why cutting up the *arteria venoſa* can we find neither air nor fumes? And whence is it that we ſee that *arteria venoſa* alwayes full of thick blood, and never full of air, ſince we ſee air remaining in the *lungs*?

If any would try the Experiment of *Galen*, and cut the windpipe of a dog being yet alive, and forcibly fill the *lungs* with air, and being filled bind them ſtreight, afterwards cutting up his breaſt he ſhall find great ſtore of air in the *lungs*, even to their utmoſt *tunicle*, but nothing in the *arteria venoſa*, nor in the *left ventricle* of the *heart*. But if in a living dog either the *heart* did attract it, or the *lungs* did pulſe it through, they ſhould do it much more in this Experiment. Yea in the adminiſtration of Anatomy blowing up the *lungs* of a dead body, who doubts but the air would enter this way, if there were any paſſage? But they do ſo much eſteem the uſe of this *arteria venoſa* for the conveying of air from the *lungs* to the *heart*, That *Hier. Fabr. ab aq. pend.* does aſſert, that the *lungs* were made for this veſſels ſake, and that it is the chiefeſt part of the *lungs*.

But I beſeech you, if the *arteria venoſa* had been made for the conveying of air, why has it the conſtitution of a *vein*?

Nature would ſtand more in need of pipes, and of annular ones, indeed ſuch as the *Bronchia* are, that ſhould be alwayes open, and never lye flat, that they might be altogether void of blood, leſt the wetneſs ſhould hinder the paſſage of the air, as it is manifeſt,

(when

(when the *lungs* are diſeas'd by the ſtuffing or leaſt entry of flegm into the *Bronchia*) when we make a whiſtling or a noiſe in our breathing.

That opinion is leſs tolerable, which (ſuppoſing that an airy and bloody matter is neceſſary for the making of vital Spirits) does aſſert, that the blood is drawn through the hidden pores of the *mediaſtin* of the *heart*, out of the *right ventricle* into the *left*, and that the air is drawn through a great veſſel, the *arteria venoſa*, out of the *lungs*; and for that cauſe, that there are more pores in the *ſeptum* of the *heart*, fitter for the production of the blood. But by my troth there are no ſuch pores, nor can they be demonſtrated.

For the ſubſtance of the *ſeptum* of the *heart* is thicker, and more compact then any part of the body, except the *bones* and *nerves*. But if there were holes, how were it poſſible, (ſince both the *ventricles* are diſtended at one time) that the one can draw any thing from the other, or that the *left* can draw blood from the *right*? And why ſhould not I rather believe that the *right* draws Spirits from the *left*, then that the *left* through the ſame holes ſhould draw blood from the *right*? But it is truly wonderfull and incoherent, that at the ſame inſtant the blood ſhould be moſt conveniently drawn through hidden and obſcure paſſages, and air through very open ones. And why, I beſeech you, have they their refuge to hidden, inviſible, incertain, and obſcure pores for the paſſage of the blood into the *left ventricle*, when there is ſuch an open way through the *arteria venoſa*? Truly it is a wonder to me, that they would rather invent or make a way through the *ſeptum* of the *heart*, which is groſs, thick, hard, and moſt compact, then through the patent *Vas Venoſum*, or elſe through the ſubſtance of the *lungs*, thin, looſe, moſt ſoft and ſpongious. Beſides, if the blood could

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paſs through the ſubſtance of the *ſeptum*, or be imbib'd by the *ventricles*, what need were there of the branches of the *Coronal arterie* divided for that purpoſe? Which is very worthy to be obſerv'd, if in a Birth (when all things are thinner and ſofter) Nature was forced to bring the blood through an oval hole, out of the *Vena Cava* through the *Arteria Venoſa*, how can it be poſſible that ſhe ſhould paſs it ſo conveniently, and with no trouble, through the *ſeptum* of the *heart*, being now made thicker after growth?

Andreas Laurentius in his *Lib.* 9. *Chap.* 11. *Quaſt.* 12. being back'd with the authority of *Galen*, and the experience of *Hollerius*, affirms, that whey, and the atter, out of the cavity of the breſt, being ſupp'd up by the *Arteria Venoſa*, can be expelled through the *left ventricle* of the *heart* and the *arteries*, together with the *Urine* and the *Excrements*; As likewiſe for the confirmation of it he relates the Caſe of a certain Melancholy man, who was freed from a Paroxiſm by the emiſſion of troubled, ſtinking, tart *urine*, by which kind of diſeaſe at laſt dying, and diſſecting the body, no ſuch ſubſtance as he piſs'd, did either appear in the *bladder* or in the *reins*, any where, but a great deal in the *left ventricle* of the *heart*, and concavity of the breaſt, whence he vaunts that he foretold the cauſe of ſuch diſeaſes. But I cannot chuſe but wonder, ſince he had gueſs'd and foretold that Heterogeneous matter could be evacuated by the ſame paſſage, that he either could not or would not ſee or affirm, that through the ſame wayes the blood could be conveniently, according to Nature, brought out of the *lungs* into the *left ventricle*.

Therefore from theſe, and many ſuch things as theſe, it is clear, that thoſe things which are before ſpoken by former Authors, concerning the motion and uſe

uſe of the *heart* and the *arteries*, do either ſeem inconvenient or obſcure, or admit of no compoſſibility, if one do diligently conſider them; therefore it will be profitable to ſearch more deeply into the buſineſs, and to contemplate the motions of the *arteries* and *heart*, not only in man, but alſo in all other creatures that have a *heart*; as likewiſe by the frequent diſſection of living things, and by much ocular teſtimony to diſcern and ſearch the truth.

ANATOMICAL EXERCISES,

CONCERNING

The motion of the *Heart*, and *Blood*, in Living Creatures.

CHAP. I.

The Causes which mov'd the Author to write.

WHen first I applyed my mind, to observation, from the many dissections of Living Creatures as they came to hand, that by that means I might find out the use of the motion of the *Heart* and things conducible in Creatures; I straightwayes found it a thing hard to be attained, and full of difficulty, so with *Fracastorius* I did almost believe, that the motion of the Heart was known to God alone: For neither could I rightly distinguish, which way the *Diastole*

Diaſtole and *Syſtole* came to be, nor when nor where the *dilatation* and *conſtriction* had its exiſtence. And that by reaſon of the quickneſs of the motion, which in ſome creatures appeared in the twinckling of an eye, like the paſſing of Lightning; ſo that ſometimes the *Syſtole* did preſent it ſelf to me from this place, and the *Diaſtole* from that place, ſometimes juſt contrary, ſometimes the motion was various, ſometimes confus'd: whence I was much troubled in mind, nor did I know what to reſolve upon my ſelf, or what belief to give to others; nor wonder'd I at that which *Andreas Laurentius* writes, That the motion of the heart, was as the ebbing and flowing of *Euripus* to *Ariſtotle*. At laſt uſing daily more ſearch and diligence, by often looking into many and ſeveral ſorts of creatures, I did believe I had hit the nail on the head, unwinded and freed my ſelf from this Labyrinth, and thought I had gain'd both the motion and uſe of the *heart*, together with that of the *arteries*, which I did ſo much deſire: Since which time I have not been afraid, both privately to my friends, and publickly in my Anatomy Lectures to deliver my opinion.

Contraction. Extenſion.

Which, as it commonly falls out, pleaſed ſome, and diſpleaſed others; Some there were that did check me, ſpoke harſhly, and found fault that I had departed from the precepts and belief of all *Anatomiſts*; Others avouching that it was a thing new, worthy of their knowledge, and exceeding profitable, requir'd it to be more plainly delivered to them. At laſt, mov'd partly by the requeſts of my friends, that all men might be partakers of my endeavours, and partly by the malice of ſome, who being diſpleas'd with what I ſaid, and not underſtanding it aright, endeavoured to traduce me publickly, I was forced to recommend

theſe things to the Preſs, that every man might of me, and of the thing it ſelf, deliver his judgement freely. But ſo much the more willing I was to it, becauſe *Hieronym. ab Aq. P.* having learnedly and accurately ſet downin a particular Treatiſe, almoſt all the parts of living creatures, left the *heart* only untouched. Laſtly, if any profit or advantage might by my induſtry in this accrew to the republick of Literature, it might perchance be granted that I had done well, and others might believe that I had not ſpent my time altogether to no purpoſe, and as the old man ſays in the *Comedy*,

No man ſo well ere laid his count to live,
But that things, age, and uſe, ſome new thing give,
That what you thought you knew, you ſhall not know,
And what you once thought beſt, you ſhall forgo.

This may perchance fall out now in the motion of the *heart*, that from hence the way being thus pervious, others truſting to more pregnant wits, may take occaſion to do better, and ſearch further.

CHAP. II.

What manner of motion the Heart has in the diſſection of living Creatures.

FIrſt then in the *hearts* of all creatures, being diſſected whilſt they are yet alive, opening the *breaſt*, and cutting up the *capſule*, which immediately environeth the *heart*, you may obſerve that the *heart* moves ſometimes, ſometimes reſts: and that there is a time when it moves, and when it moves not.

This is more evident in the *hearts* of colder creatures, as the *Toads*, *Serpents*, *Frogs*, *Houſe-Snails*, *Shrimps*, *Creviſes*, and all manner of little *Fiſhes*. For it ſhews it ſelf more manifeſtly in the hearts of hotter bodies, as of *Dogs*, *Swine*, if you obſerve attentively till the *heart* begin to die, and move faintly, and life is as it were departing from it. Then you may clearly and plainly ſee that the motions of it are more ſlow, and ſeldom, and the reſtings of it of a longer continuance: and you may obſerve and diſtinguiſh more eaſily, what manner of motion it is, and which wayes it is made, in the reſting of it, as likewiſe in death, the *heart* is yielding, flagging weak, and lyes as it were drooping.

At the motion, and whilſt it is moving, three things are chiefly to be obſerved.

1. That the *heart* is erected, and that it raiſes it ſelf upwards into a point, inſomuch that it beats the breaſt at that time, ſo as the pulſation is felt outwardly.

2. That there is a *contraction* of it every way, eſpecially of the *ſides* of it, ſo that it appears leſſer, longer, and contracted. The *heart* of an *Eel*, taken out, and laid upon a trencher, or upon ones hand, doth evidence this: It appears likewiſe in the *hearts* of little Fiſhes, and of thoſe colder *Animals* whoſe hearts are *ſharp at top, and long*.

3. That the *heart* being graſp'd in ones hand whilſt it is in motion, feels harder. This hardneſs ariſes from *tention*, like as if one take hold of the *tendons* of ones arm by the *Elbow* whilſt they are moving the fingers, ſhall feel them bent and more reſiſting.

4. 'Tis moreover to be obſerved in *Fiſh*, and *colder Animals* which have blood, as *Serpents*, *Frogs*, at

at that time when the heart moves it becomes whitish, when it leaveth motion it appears full of sanguine colour. From hence it seemed to me, that the motion of the *heart* was a kind of *tention* in every part of it, according to the *drawing* and *constriction* of the *fibers* every way; because it appear'd that in all its motions, it was erected, received vigour, grew lesser, and harder, and that the motion of it was like that of the *muscles*, where the *contraction* is made according to the drawing of the *nervous parts, and fibers*, for the *muscles* whilst they are in motion, and in action, are envigorated, and stretched, of soft become hard, they are uplifted, and thickned, so likewise the *heart*.

From which observations with good reason we may gather that the *heart* at that time whilst it is in motion, suffers constriction, and is thickned in its outside, and so streightned in its *ventricles*, thrusting forth the blood contained within it: which from the fourth observation is evident, because that in the *tention* it becomes white, having thrust out the blood contained within it, and presently after in it *relaxation*, and rest, a purple and crimson colour returns to the *heart*. But of this no man needs to make any further scruple, since upon the inflicting of a wound into the *cavity* of the *ventricle*, upon every motion, and pulsation of the *heart*, in the very *tention*, you shall see the blood within contained to leap out.

So then these things happen at one and the same time, the *tention* of the heart, the *erection* of the *point*, the beating (which is felt outwardly) by reason of its hitting against the *breast*, the incrassation of the sides of it, and the forcible protrusion of the blood by constriction of the *ventricles*.

Hence the contrary of the commonly received opinion appears, which is, that the *heart* at that time when it beats against the *breast*, and the pulsation is outwardly felt, it is believ'd that the *ventricles* of the *heart* are dilated, and replete with blood, though you shall understand that it is otherwise, and that when the *heart* is contracted it is emptied. For that motion which is commonly thought the *Diastole* of the *heart*, is really the *Systole*, and so the proper motion of the *heart* is not a *Diastole* but a *Systole*, for the *heart* receives no vigour in the *Diastole*, but in the *Systole*, for then it is extended, moveth, and receiveth vigour.

Neither is that to be allowed, though it is confirmed by a comparison alleadged by the *Divine Vesalius*, of a wreath of *Oziers*, meaning of many twigs joyn'd together in fashion of a *Pyramide*: that the *heart* doth not only move by the streight *fibers*, and so whilst the top is brought near to the bottom, the sides of it are dilated round about, and do acquire the form of a little *gourd*, and so take in blood, (for according to all the drawing of the *fibers* which it has, the *heart* is stiffned, and gather'd together) But that the outside and substance of it are rather thickned and dilated, and that whilst the *fibers* are stretched from the top of the *corner* to the bottom, the sides of the *heart* do not encline to an *orbicular figure*, but rather contrary, as every *fiber* circular lyes plac'd, does in its contraction encline to streightness, and as all the *fibers* of the *muscles* whilst they are contracted and shortned of their length, so towards the sides they are extended, and are thickned after the same fashion as the bodies of the *muscles*.

To this add, that not only in the motion of the *heart*,

heart, by erection and incraſſation of the ſides of it, it ſo falls out, that the *ventricles* are ſtreightned, but moreover all the ſides inwardly are girt together as it were with a *nooſe*, for expelling the blood with greater force, by reaſon that thoſe *fibers* or little *tendons*, amongſt which there are none but ſtreight ones, (for thoſe in the outſide are circular) called by *Ariſtotle Nerves*, are various in the *ventricles* of the *hearts* of greater creatures, whilſt they are contracted together with a moſt admirable frame.

Neither is it true which is commonly believ'd, that the *heart* by any motion or diſtention of its own doth draw blood into the *ventricles*, but that whilſt it is moved and bended, the blood is thruſt forth, and when it is relax'd and falls, the blood is received in manner as follows.

CHAP. III.

What manner of motion the Arteries have in diſſection of living creatures.

THere occurs in the motion of the *heart* theſe things further to be obſerv'd, which have relation to the moving and pulſation of the *arteries*.

1. That whilſt there is a tention, contraction of the *heart*, and a percuſſion of the *breaſt*, and an apparent *Syſtole*, the *arteries* are dilated, do beat, and are in their *Diaſtole*. In like manner when the right *ventricle* thruſts out the blood contained in it, the *arterious vein* beats and is dilated, together with the reſt of the *arteries* of the body.

2. When the left *ventricle* ceaſeth to move, beat,

and to be contracted, the beating of the *arteries* ceases: nay when the *tention* is but faint, the pulsation of the *arteries* is hardly to be perceived, and so likewise in the *arterial vein*, when the right ceases.

3. Likewise cutting or piercing any *arterie* in the very *tention* of the left *ventricle* the blood is forcibly thrust out of the wound, so cutting the *arterial vein* at the same time, and in the *tention* and contraction of the *right ventricle*, you shall see the blood to burst out forcibly from thence.

So likewise in *Fishes*, cutting the *conduit pipe*, which leads from the *heart* to the *gills*, at which time you shall see the *heart* stiff, and contracted, from thence you shall see the blood forcibly thrust out.

Lastly, as in the cutting of any *arterie*, the blood leaps out sometimes farther, sometimes nearer, you shall find the out-leaping to be just with the *arterial Diastole*, at which time the *heart* strikes the *breast*, and at that time then when it appears that the *heart* is in its *tention*, and contraction, it is in its *Systole*, and that the blood is thrust out with the same motion.

From hence, this against the Common rule appears to be clear, that the *arterial Diastole* is at the same time with the *Systole* of the *heart*, and that the *arteries* are fill'd and distended, by reason of the immission and intrusion of blood made by the constriction of the *ventricles* of the *heart*; as likewise that the *arteries* are stretched, because they are fill'd like Bags or Satchels, and are not fill'd because they are blown up like Bellows: and for the same cause do all the *arteries* of the body beat, by reason of the *tention* of the *left ventricle* of the *heart*, as the *arterial vein* from the *tention* of the *right*.

Lastly, That the pulsation of the *arteries* arises from

from the impulſion of blood from the *left ventricle*; juſt ſo, as when one blows into a glove, he ſhall ſee all the fingers ſwell up together, and aſſimulate this pulſation. As alſo according to the *tention* of the *heart*, the pulſations are greater, more vehement, more frequent, ſwifter, keeping the number, quantity, and order, of the beating of the *heart*.

Nor is it to be expected, that becauſe of the motion of the blood there ſhould be a certain diſtance of time betwixt the conſtriction of the *heart*, and the dilatation of the *arteries*, (eſpecially of thoſe that are furtheſt diſtant) that they be not at the ſame inſtant, becauſe that in a *Baſon* (as likewiſe in a Drum, and long pieces of Timber) the ſtroke and the motion are alike ſoon at both extremes: ſince the caſe here is juſt as in the blowing up of a Glove, or a Bladder. Hence *Ariſt.* 3. *Anim. C.* 9. *de reſp. Cap.* 15. *The blood* (ſays he) *of all living creatures, beats within their veins*, (meaning the *arteries*,) *and with a continual motion moves every where: ſo do all the veins beat together, and by turns, becauſe they have their dependance upon the heart. But it does alwayes move, wherefore they likewiſe move, and in order to its motion when it doth move.*

We muſt obſerve with *Galen*, that the *arteries* were named *veins* by the ancient Philoſophers. I chanced on a time to ſee and have in hand, an accident which did moſt plainly confirm this to me to be true: A certain perſon had a great ſwelling which did beat on the *right ſide* of his *throat* near to the deſcent of the *ſubclavial arterie*, into the *armpits*, call'd *Aneuriſma*, begotten by the corroſion of the *arterie* it ſelf, which grew bigger and bigger every day, being filled with the immiſſion of blood

from the *arterie* at every *pulsation*; which was found upon the cutting up of his body after he was dead. In this man the *pulse* of his *arm* upon that side, was very weak, by reason that the greater portion and influx of blood was turned into the swelling, and so diverted.

Wherefore, whether it be by compression, stuffing, or interception, that the motion of the blood through the *arteries* be hindered, in that case the furthermost *arteries* do beat less, seeing the pulse of the *arteries* is nothing but the impulsion of the blood into the *arteries*.

CHAP. IV.

What manner of motion the Heart, and the ears of it, have in living Creatures.

BEsides these, there are to be observed such things as belong to the *ears*, which *Gaspar Bauhinus P. C. Anat.* 22. 21. and *Johan. Riolanus*, men very learned, and skilfull *Anatomists* have observed, and advises us, that if in the live dissection of any *animals* you have good regard to the motion of the *heart*, you shall see four motions, distinct both in time and place: with leave of such eminent men be it spoken, there are four motions distinct in place, but not in time; for both the *ears* move together, and both the *ventricles* move together, so that there are four motions distinct in place, only at two times, and it is thus,

There are as it were at one time two motions, one of the *ears*, and another of the *ventricles* themselves, for they are not just at one instant, but the motion

motion of the *ears* goes before, and the motion of the *heart* follows; and the motion seems to begin at the *ears*, and to pass forward to the *ventricles*; when all things are already in a languishing condition, (the *heart* dying away, as it is both in *Fishes*, and other *colder animals* which have blood) there intercedes some short resting time betwixt these two motions, and the *heart* being as it were weakned, seems to answer the motion, sometimes swifter, sometimes slower; last of all drawing towards death, it ceases to answer by its motion, and only by nodding its head seems as it were to give consent, and moves so insensibly, that it seems only to give a sign of motion to the *ears*: So the *heart* first leaves beating, before the *ears*, so that the *ears* are said to out-live it: the *left ventricle* leaves beating first of all, then its *ear*, then the *right ventricle*, last of all (which *Galen* observes) all the rest giving off and dying, the *right ear* beats still: so that life seems to remain last of all in the right. And whilst by little and little the *heart* is dying, you may see after two or three beatings of the *ear*, the *heart* will, being as it were rowsed, answer, and very slowly and hardly endeavour and frame a motion.

But this is chiefly to be observed, that after the *heart* has left beating, and the *ears* are beating still, putting your finger upon the *ventricle* of the *heart*, every pulsation is perceived in the *ventricles*, just after the same manner as we said the pulsations of the *ventricles* were felt in the *arteries*, a distention being made by impulsion of blood: and at this time, the *ears* only beating, if you cut away the *point* of the *heart* with a pair of *Scissors*, you shall see the blood flow from thence at every pulsation of the *ear*, so that from thence it appears which way the blood

blood comes into the *ventricles*, not by attraction or diſtention of the *heart*, but ſent in by the impulſion of the *ears*.

It is to be obſerved, that all thoſe which I call pulſations, both in the *ears*, and in the *heart*, are contractions, and that the *ears* are evidently firſt contracted, and afterwards the *heart* it ſelf. For the *ears* whilſt they move and beat, become whitiſh, eſpecially when there is little blood in them, for they are fill'd as the *cellars* and *treaſuries* of blood, by the compreſſive motion of the *veins*, and the tending of the blood to its *proper Centre*. Nay further, it is moſt evident, in the *ends* and *extremities* of them, that the whiteneſs ariſes meerly from the contraction of them.

In *Fiſhes*, and *Frogs*, and the like, having but one *ventricle* of the *heart* (for in lieu of one ear they have a *little bladder* plac'd at the *bottom of their heart* full of blood) you ſhall moſt evidently ſee the *bladder* firſt contracted, and the contraction of the *heart* to enſue.

Notwithſtanding I thought fit to inſert thoſe things which were of a contrary courſe, the *heart* of an *Eel*, as alſo of ſome *Fiſhes*, and living creatures being tane out beats without *ears*, nay though you cut it in pieces, you ſhall ſee the pieces when they are aſunder contract and dilate themſelves, ſo that in ſuch, after the motion of the *ears*, the *heart* does leap and beat: But this perchance is only proper to ſuch creatures, which are more tenacious of life, whoſe *radical moiſture* is more glutinous, fatter, tougher, and not ſo eaſie to be diſſolv'd. This alſo does appear in the fleſh of *Eels*, which after the skinning, exenteration, and cutting in pieces, retains motion.

This

This is certain that upon a time trying an experiment *upon a Dove*, after that the *heart* had quite left motion, and that the *ears* had a while given over, I wetted my finger with ſpittle, and being warmed kept it a while upon the *heart*, by this fomentation, as if it had received ſtrength and life afreſh, the *heart*, and its ears began to move, to contract, and open, and did ſeem as it were recall'd back again from death.

But beſides all theſe I have often obſerv'd that after the *heart* it ſelf, and even its right *ear*, had at the very point of death left off beating, there manifeſtly remain'd in the very blood which is in the *right ear*, an obſcure motion, and a kind of inundation, and beating, that is to ſay, ſo long as it ſeem'd to be poſſeſſ'd with any blood or ſpirit.

A thing of the like nature, in the firſt generation of a living creature moſt evidently appears in a Hens egg within ſeven dayes after her ſitting, firſt of all there is in it a drop of blood, which moves, as *Ariſtotle* likewiſe obſerv'd, which receiving encreaſe, and the *Chicken* being form'd in part, the *ears* of the *heart* are faſhioned, which beating there is alwayes life; then afterwards within a few dayes the body beginning to receive its lineaments, then likewiſe is the body of the *heart* framed, but for ſome dayes it appears whitiſh and without blood, nor doth it beat and move as the reſt of the body; as alſo I have ſeen in a child after three moneths, the *heart* to be alſo form'd, but whitiſh, and without blood; in the *ears* of which notwithſtanding there was great ſtore of blood, and of a crimſon colour: ſo likewiſe in the egg when the *Chick* was new form'd, and encreaſed, the *heart* began likewiſe to encreaſe, and to have *ventricles* in which it

began

began to receive blood and pass it through.

So that if a man will more narrowly pry into the truth, he will not say, that the *heart* is the first thing that lives, and last that dies, but rather the *ears* (and in Snakes, Fishes, and such like creatures, the part which is instead thereof) and that it both lives before the *heart*, and dies after it.

Nay it's doubtfull too, whether or no before them also the spirit and blood have an obscure beating, which to me it seem'd to retain after death, or whether we may say that with this beating the life begins, seeing the Sperm, and prolifique Spirit, of all living creatures, goes from them with a kind of leaping, as if it self were a living creature. So Nature in death making as it were a recapitulation, returns upon her self with a retrograde motion, from the end of her race to the beginning of it, from whence she first issues thither she returns, seeing the generation of living creatures, from not being a living creature, is to be a living creature, as from a non-entity to be an entity, so by the same steps, corruption passes from an entity, to a non-entity; whence it is, that that which in living creatures is last made, fails first, and that which is first made, fails last.

I have likewise observ'd, that there is really a heart in all animals, and not only (as *Aristotle* says) in the greater sort, and such as have blood, but likewise in lesser, and such as have none, as those that are crusted without, or have shels, as house-*Snails*, *Crabfish*, *Crevises*, *Shrimps*, and in many others, nay in *Wasps*, *Hornets*, and in *Gnats*, by an optick glass made for the discovery of the least things, in the upper end of that place which is called their tail, I saw the *heart* beat, and shewed it to others.

But

But in those creatures which have no blood, the *heart* beats very slowly, and with deliberate strokes, as it does in other creatures which are dying, and is contracted leisurely, as in *Snails* is easie to discern, whose *heart* you shall find in the right side at the bottom of that *Orifice*, which it seems to open and shut for taking of air, and from whence it casts out foam, dissecting it at the top near the place which is answerable to the *liver*.

But it is to be observed likewise, that in Winter, and colder seasons, some creatures which have no blood, such as is the *Snail*, have nothing which beats, but do rather seem to be like plants; as likewise the rest, which for that cause are called *Plant-animals*. It is likewise to be observed, that in all creatures which have *hearts*, there are *ears* likewise, or some thing answerable to them, and wheresoever the *heart* has two *ventricles*, there are two *ears*, but not contrarily. But if you observe the fashioning of a Chick in the egg, first of all there is in it as I said only a *bladder* or drop of blood, which beats, and encreasing afterwards the *heart* is perfected; so in some creatures (as not reaching a further perfection) there is a certain little *bladder* only like a point, red or white, as the beginning of life, as in *Bees*, *Wasps*, *Snails*, *Shrimps*, *Crevises*.

There is found here with us a sort of very little Fish, called in English, a *Shrimp*, and in Low Dutch *Een Garneel*, usually taken in the Sea, and in the River of *Thames*, all the body of which is transparent: This little Fish I have often shewn in water to some of my special friends, so that we could clearly discern the motion of the *heart* in that creature, the outward parts nothing at all obstruct-

ing

ing our ſight, as if it had been through a window. In a Hens egg I ſhewed the firſt beginning of the Chick, like a little cloud, by putting an egg off which the ſhell was taken, into water warm and clear, in the midſt of which cloud there was a point of blood which did beat, ſo little, that when it was contracted it diſappeared, and vaniſh'd out of our ſight, and in its dilatation, ſhew'd it ſelf again, red, and ſmall, as the point of a needle; inſomuch as betwixt being ſeen, and not being ſeen, as it were betwixt being, and not being, it did repreſent a beating, and the beginning of life.

CHAP. V.

The action and office of the motion of the Heart.

I Confidently believe then, that out of theſe and the like obſervations, it will be found that the motion of the *heart* is after this manner.

Firſt of all the *ear* contracts it ſelf, and in that contraction throws the blood with which it abounds, as the head-ſpring of the *veins*, and the *cellar* and *ciſtern* of *blood*, into the *ventricle* of the *heart*, which being full, ſtraightway the *heart* raiſes it ſelf, ſtretches all the *nerves*, contracts the *ventricles*, and makes a pulſation: by which pulſation it continually thruſts that blood, (which by the *ears* is ſent in) forth into the *arteries*, the *right ventricle* into the *lungs*, through that veſſel which is called the *vena arterioſa*, but is indeed both in its place and function, and every thing elſe, an *arterie*; the *left ventricle* into the *aorta*, and ſo by the *arteries* into the whole body.

Thoſe

Thoſe two motions, the one of the *ears*, the other of the *veniricles*, are ſo done in a continued motion, as it were keeping a certain harmony, and number, that they are both done at the ſame time, and one only motion appears, eſpecially in hotter creatures, whilſt they move with a ſudden motion. Nor is this otherwiſe done, then when in *Engines*, one wheel moving another, they ſeem all to move together; and in the lock of a piece, by the drawing of the ſpring, the flint falls, ſtrikes the ſteel, fires the powder, enters the touch-hole, diſcharges, the balls fly out, pierces the mark, and all theſe motions by reaſon of the ſwiftneſs of them, appear in the twinkling of an eye: So likewiſe in the deglutition, the meat or drink is thrown into the *jaws*, the *larinx* is ſhut cloſe, by its own *muſcles*, and the *Epiglottis*, the top of the *weaſon*, is lifted up, and opened by its *muſcles*, juſt as a ſack is raiſed to be filled, and opened that it may receive; it thruſts down the meat or drink being receiv'd, by the *thwarting muſcles*, and with the *long muſcles* ſucks it down; yet notwithſtanding that all theſe motions are made by ſeveral and contradiſtinct *organs* whilſt they are done in harmony and order, ſeem but to make one motion and action, which they call ſwallowing.

So it comes to paſs clearly, in the motion and action of the *heart*, which is a kind of ſwallowing, and transfuſion of blood out of the veins into the arteries. And if any man carefully obſerving this, ſhall diligently ſearch the motion of the *heart* in the diſſection of any living thing, he ſhall ſee not only that which I have ſaid, that the *heart* erects it ſelf, and makes one continued motion with the *ears* of it, but likewiſe a certain motion and inclination ſide-

wayes,

wayes, and an obſcure leaning that way, in order to the draught of the *right ventricle*, ſo carrying on the work. As we may ſee when a Horſe drinks, and ſwallows the water, at every gulp the water is ſup'd down into the belly, which yields a certain noiſe and pulſe to him that heeds him, and touches him; even ſo it comes to paſs, that whilſt ſome portion of the blood is drawn out of the *veins* into the *arteries*, there is a beating which is heard within the breaſt.

The motion of the *heart* then is after this manner, and the transfuſion and propulſion by mediation of the *arteries* is one of the actions of the *heart*, ſo that the pulſation which we feel, is nothing elſe but only the impulſion of the blood by the *heart*.

But whether or no the *heart* contribute any thing elſe to the blood, beſides the *tranſpoſition*, *local motion*, and *diſtribution* of it, we muſt enquire afterwards, and collect out of other obſervations. Let this ſuffice for the preſent, that it is ſufficiently evidenced, that in the beating of the *heart* the blood is transfuſed and drawn out of the *veins*, into the *arteries*, through the *ventricles* of the *heart*, and ſo diſtributed into the whole body.

But this all do in ſome manner grant and gather from the fabrick of the *heart*, and from the *figure*, *place*, and *uſe* of the *Portals*, yet ſtumbling as it were in a dark place, they ſeem to be dim-ſighted, and clamper up divers things, which are contrary and inconſiſtent, and ſpeak many things at random (as we ſhewed before.) One thing ſeems to me to have been the chief cauſe of doubt and miſtake in this buſineſs, which is, the contexture in a man of the *heart* and *lungs*; For when they did ſee the *vena arteriosa*, and the *arteria venoſa*, coming likewiſe

wiſe into the *lungs*, and there to diſappear, it could not ſink with them either how the *right ventricle* ſhould diſtribute the blood into the body, or how the *left ventricle* ſhould draw it out of the *vena Cava*. This *Galens* words do teſtifie in his book *De plac. Hip. & Plat.* 6. Where he inveighs againſt *Eroſiſtratus*, concerning the beginning and uſe of the *veins*, and the concoction of the blood. *You will anſwer* (ſayes he) *that it is ſo ordained, that the blood be prepared in the Liver, and ſo carried to the Heart, there to receive its proper form and abſolute perfection: which truly ſeems not without reaſon; for no perfect and great work is done ſuddenly, at one attempt, and gains all its refining from one inſtrument. Which if it be ſo, ſhew us another veſſel which draws out the blood, being abſolutely perfected from the heart, and diſpoſes of it as the arteries do of the ſpirits through the whole body.*

See here an opinion which carries reaſon with it left and rejected by *Galen*, becauſe (beſides not perceiving the paſſage,) he could not find a veſſel which from the *heart* ſhould diſtribute the blood into the whole body.

But if at that time in the defence of that opinion (which is now ours, and in all things elſe agreeable to reaſon by *Galens* own confeſſion) one ſhould with his finger have pointed out the great *arterie* diſpenſing the blood from the *heart* into the whole body, what would that Divine man, moſt ingenious, and moſt learned, have anſwered? I wonder whether he would have ſaid that the *arteries* diſtribute ſpirits and not blood? certainly he ſhould not by this ſufficiently have confuted an *Eroſiſtratus*, who did imagine the ſpi-

rits to be contained in the *arteries* only; but ſhould in the mean time contradict himſelf, and baſely deny that, which in one of his own Books he ſtiffly maintains to be true, proves it by many and ſtrong arguments, and by experiments demonſtrates it, that blood is naturally contain'd in the *arteries*, and not *ſpirits*.

But if that Divine man, as he does often in the ſame place, do grant that all the *arteries* of the body do ariſe from the great *arterie*, and it from the *heart*, and profeſſing likewiſe that thoſe *three pointed doors* plac'd in the *Orifice* of the *Aorta* do hinder the return of the blood into the *heart*, and that nature had never ordain'd them for the beſt of our intralls, unleſs it had been for ſome ſpecial Office, I ſay, if the father of the Phyſicians ſhould grant all theſe things, and in the ſame very words as he does in his forementioned book, I do not ſee how he could deny that the great *arterie* was ſuch a veſſel as did carry the blood, after it had received its abſolute perfection, out of the *heart* into the whole body: Or perchance he would ſtill continue to be doubtful, (as all the reſt ſince his time to this very day) becauſe not ſeeing the contexture of the *heart* with the *lungs* he was ignorant of the ways by which the Blood could be carried into the *arteries*, which doubt does not a little perplex the *Anatomiſts* when always in diſſections they find the *arteria venoſa* and the left *ventricle* full of thick knotty black blood, ſo that they are forc'd to affirm that the blood ſwets through the encloſer of the *heart* from the *right ventricle* to the *left*; but this way I have ſufficiently refuted already, therefore there muſt another way be prepared and laid open, which

which being found, there can, I imagine, be no difficulty, which can hinder any body from granting and confessing those things which I propounded before of the pulsation of the *heart*, and dispensation of the blood by the *arteries* into the whole body.

CHAP. VI.

By which ways the blood is carried out of the vena cava, into the arteries, or out of the right ventricle of the heart into the left.

Since it is probable, that the connexion of the *heart* with the *lungs* has given this occasion of mistake, they are to be blamed in this, who whilst they desire to give their verdict, to demonstrate, and understand all parts of living creatures, look but into man only, and into him being dead too, and so do no more to the purpose, than those, who seeing the manner of Government in one Common-wealth, frame Politicks, or they who knowing the nature of one piece of Land, believe that they understand agriculture, or as if from one Particular proposition, they should go about to frame Universal arguments.

Nevertheless were they but as well practis'd in the dissection of creatures, as they are in the Anatomy of mens carcases, this business, which keeps them all in doubt and perplexity, would in my opinion seem clear without all difficulty.

First of all in Fishes having but one *ventricle* of the *heart* (as having no *lungs*) the thing is clear

enough. For it is certain, that it may be confirmed before our eyes, that the *bladder* of blood, which they have at the bottom of the *heart*, answerable to the *ear* of the *heart*, sends the blood into the *heart*, and that the *heart* does afterward, through a pipe or *artery*, or something answering to an *artery*, openly transfuse it, both by our own view, and also by cutting the *arterie*, the blood leaping out upon every pulsation of the *heart*.

You may likewise see the same afterward easily in all other creatures, in which there is but one *ventricle* only, or something answerable to it, as in the *Toad*, *Frogg*, *Serpents*, house-*Snails*, which although they are said in some manner to have *lungs*, because they have a voice (of the frame of whose *lungs* I have many observations by me, which are not proper for this place) yet from our own eyesight it is clear, after the same manner in them that the blood by the pulsation of the *heart* is brought out of the *veins* into the *arteries*, the way of it open, patent, manifest, no occasion or doubt of difficulty at all. For the case is just so with them as it might be with a man, the enclosure of whose *heart* were pierced through, or taken away, and so both the *ventricles* become one, I believe no man then would doubt which way the blood should go out of the *veins*, into the *arteries*.

And seeing there are more creatures which have no *lungs*, than there are which have, and more which have but one *ventricle*, than there are which have two, we may very well averr for the most part, and almost in all, that the blood is transfus'd out of the *veins*, into the *arteries*, through the bosom of the *heart* by an open passage.

But

But I conceiv'd with my ſelf that it is plainly ſeen too in thoſe *Embryons* which have *hearts*.

In a birth there are four veſſels of the heart, the *vena cava*, the *vena arterioſa*, *arteria venalis*, and the *aorta*, or *arteria magna*, and are otherwiſe united then in one come to age, which all Anatomiſts know well enough.

The firſt touch and union of the *vena cava* with the *arteria venoſa*, which comes to paſs before the *vena cava* opens it ſelf into the *right ventricle* of the *heart*, or ſends out the Coronal *vein*, a little above its out-going from the *liver*, diſplays unto us its orifice ſide-wayes, that is to ſay, a hole, wide and large, of an oval figure, made through paſſageable, from the *vena cava* into that *arterie*: Inſomuch as through that hole the blood may freely and abundantly paſs out of the *vena cava*, into the *arteria venoſa*, and the left *ear* of the *heart*, and ſo to the left *ventricle*. There is moreover againſt that place which looks towards the *arteria venoſa* a *membrane* thin and hard, like a cover, which afterwards in thoſe which grow to riper years, covering this hole, and growing together every way, does quite ſtop it, and takes away almoſt all ſign of it. This * *membrane*, I ſay, is ſo ordained, that hanging looſely with its own weight, it makes way into the *lungs*, and *heart*, and is turned up, giving paſſage to the blood which flows from the *vena cava*, but hinders it from flowing back into the *cava* again. So that from hence we may imagine in an *Embryon*, that the blood ought continually to paſs through this hole into the *arteria venoſa*, out of the *vena cava*, and ſo into the left *ear*

* Septum.

of the *heart*, and after it is enter'd, that it can never return.

The other union is that of the *vena arteriosa*, (which comes to pass after that that *vein* coming out of the *right ventricle*, is divided into two branches) and it is as it were a third *trunk*, or *arterial conduit-pipe*, divers from the two former, from hence crookedly drawn, and perforate into the *arteria magna*; so that in the dissection of *Embryons*, there appears as it were two *aortas*, or two roots of the *great arterie*. This *conduit* likewise in those that come to riper age is attenuated by little and little, and fades away, and at last is quite dried up, and lost, like the *Umbilical vein*. This *arterial conduit-pipe* hath no *membrane* to hinder the motion of blood backward, or forward, for there are in the orifice of that *vena arteriosa*, of which this *conduit-pipe* as I said before is a *branch*, three **doors* of the fashion of a Σ which appear outwardly and inwardly, and do easily give passage to the blood flowing into the *right ventricle* by this way, but on the contrary hinder any thing which may flow from the *arterie* or the *lungs* into the *right ventricle*; which they shut very close: So that here we have reason to think, that in an *Embryon* when the *heart* contracts it self, the blood must alwayes be carried out of the *right ventricle* into the *arteria magna* by this way.

* Valvulæ.

In answer to that which is commonly spoken, that these two conjunctions, so great, so open, so wide, were made for the nourishing of the *lungs*, and that in those who arrive to riper age, when the *lungs* by reason of their heat and motion require

require more abundant nutriment, they ſhould be tane away, and made up, is an invention improbable, and inconſiſtent. And that is likewiſe falſe which they ſay of the *heart* of an *Embryon*, that it is idle and does nothing, moves not at all: whence it comes to paſs, that Nature was forc'd for the nouriſhing of the *lungs* to make thoſe paſſages; when by our own eyes it is made plain to us, that both in an egg whereon a Hen hath ſate, and in *Embryons* newly cut out of the womb, the *heart* doth move as in thoſe of riper age; and likewiſe, that Nature is preſſed with no ſuch neceſſity: Of which motion not only theſe my eyes have often been Witneſſes, but likewiſe *Ariſtotle* himſelf affirms; *The pulſe* (ſays he) *appears at the very beginning in the conſtitution of the heart, which is found in the diſſection of living creatures, and by an egg in the forming of the Chick.* But we alſo obſerve, that thoſe paſſages are open and free, as well in men, as alſo in other creatures, not only to the time of the birth, which the Anatomiſts have obſerv'd, but likewiſe many moneths after: yea in ſome for many years, if not all their life-time, as in the *Gooſe*, and very many Birds. Which thing perchance did deceive *Botallus*, ſo that he affirm'd, That he had found a new paſſage for the blood, out of the *vena cava* into the *left ventricle* of the *heart*. And I do confeſs, That when I my ſelf firſt found this in a *Rat* of full growth, that I did imagine ſome ſuch thing. From which it is underſtood, that in the unripe births of mankind, and likewiſe in others, in which theſe unions are not taken away, this very thing falls out, that the *heart* by its motion brings forth the blood from

the *vena cava* openly, and by very patent wayes, by the drawing of both its *ventricles*. For the *right* receiving the blood from the *ear*, thrusts it forth through the *vena arteriosa*, and its branch called *canalis arteriosus*, into the great *arterie*. Likewise, the *left* at the same time by the mediation of the motion of the *ear*, receives that blood, which is brought into the *left ear* through that oval hole from the *vena cava*, and by its *tention* and *constriction* thrusts it through the root of the *aorta* into the *great arterie* likewise. So in *Embryons* whilst the *lungs* are idle, and have no action nor motion (as if there were none at all) Nature makes use of both the *ventricles* of the *heart*, as of one for transmission of blood. And so the condition of *Embryons* that have *lungs* and make no use of them, is like to the condition of those creatures which have none at all.

Therefore in these likewise the truth appears as clearly, that the *heart* by its pulsation brings forth, and transfuses the blood out of the *vena cava*, into the great *arterie*, and by as open ways as if both the *ventricles* (as I said before) were made pervious to one another, by taking away the partition betwixt them. Therefore seeing for the most part these ways are open in all creatures at some times, which do serve for transmission of blood through the *heart*, it now remains that we enquire either why in some creatures, as in men, and those hotter, and of riper age, we do hold that not to be performed through the substance of the *lungs*, which nature did before in an *Embryon* through those passages (at that time when there was no use of *lungs*,) which she seems to have made of force for

want

want of passage through the *lungs*. Or why it is better that Nature (for Nature always does that which is best) hath altogether shut up those open ways, of which she before made use in the *Embryon*, and in the birth, and in all other creatures does make use of, nor in the lieu of them hath found out any other passage for the blood, but hinders it altogether after this manner.

So then the business is arriv'd to this, that to those who search for the veins in men (by which the blood passes out of the *vena cava* in the left *ventricle*, and into the *arteria venosa*) it were more worthy their pains, and wiselier done, if from the dissection of living creatures they would search the truth, why in greater, and more perfect creatures, and those of riper age, nature would rather have the blood to be squeezed through the *streyner* of the *lungs*, than through most patent passages, as in other creatures: and then they would understand that no other way nor passage could be excogitated.

Whether this be, because that greater and perfecter creatures are hotter, and when they come to be of age, their heat is apter to be suffocated and to be inflamed, and therefore the blood is streyn'd and sent through the *lungs* that it may be temper'd by breathing in the air upon it, and freed from over-heating and suffocation, or some such other thing. But to determine and give a reason of this is nothing else but a search for what the *lungs* were made. And thus much concerning them and their use, and all manner of cooling, of the necessity and use of air, and the like, of several and different organs made in *animals*. For this cause although by observation I have found out a great many

many things, yet leſt I ſhould ſeem by ſtraying from my Purpoſe, of the motion of the *heart*, to go beſides my intention, and leave my task to confute the buſineſs, and decline it; I ſhall leave theſe things fitter to be ſet forth in a Treatiſe by themſelves; and that I may return to my former purpoſe, I will go on to prove what remains. And firſt I prove, that in the more perfect *Animals*, and thoſe come to age, as in Man, the blood may paſs from the *right ventricle* of the *heart*, by the *vena arteria*, into the *lungs*, and from thence through the *arteria venoſa* into the *left ear*, and from thence into the *left ventricle* of the *heart*, and then that it is ſo,

CHAP. VII.

That the blood does paſs from the right ventricle of the heart, through the ſtreyner of the lungs, into the arteria venoſa, and left ventricle of the heart.

IT is well enough known that this may be, and that there is nothing which can hinder if we conſider which way the water paſſing through the ſubſtance of the earth, doth procreate Rivulets and Fountains; or if we do conſider how *ſweat* paſſes through the *skin*, or how *urine* flows through the *ſtreyner* of the *reins*: It is to be taken notice of in thoſe that make uſe of the waters of the *Spaw*, or *de la Madonna*, as they call them in *Padua*, or other brackiſh or vitriolated waters; or thoſe who in carrowſing ſwill themſelves with drink, that in an

an hour or two they piſs all this through their bladder. This great quantity ought to ſtay a while in concoction, it ought to flow through the *liver*, (as they confeſs that the juyce of the nouriſhment we receive doth twice a day) ſo ought it through the *veins*, through the *ſtreyner* of the *reins*, and through the *ureters* into the *bladder*.

Thoſe therefore which I hear denying, that blood, yea the whole maſs of blood, may paſs through the ſubſtance of the *lungs*, as well as the nutritive juyce through the *liver*, as if it were impoſſible, and no wayes to be believed; It is to be thought that thoſe kind of men, I ſpeak with the Poet, where they like, they eaſily grant, where they like not, by no means: Here where need is, they are afraid, but where no need is they are not afraid to averr. The *ſtreyner* of the *liver*, and of the *reins* too, is much thicker then that of the *lungs*, becauſe they are far thinner woven, and of a ſpongious ſubſtance, if they be compared to the *liver* and *reins*.

In the *liver* there is no impulſive, no ſtrength forcing, in the *lungs*, the blood is thruſt againſt them by the impulſion of the *right ventricle* of the *heart*, by which impulſion there muſt neceſſarily follow a diſtenſion of the veſſels, and poroſities of the *lungs*. Beſides, the *lungs* in reſpiration riſe and fall, *Galen de uſu part.* By which motion it follows of neceſſity, that the poroſities of them and their veſſels are open'd and ſhut, as it falls out in ſponges, and all things of a ſpongy ſubſtance when they are conſtricted and dilated again; On the contrary, the *liver* is at reſt, nor is it ſeen at any time to be ſo conſtricted and dilated.

Laſt

Laſt of all, Since through the *liver*, there is none but affirms, that the juyce of all things we receive may paſs into the *vena cava*, both in Men, Oxen, or the greateſt creatures, and that for this reaſon, becauſe it muſt paſs ſome way into the *veins* if there be any nutrition, and there is no other way, and for that cauſe they are forced to affirm this: Why ſhould they not likewiſe believe this of the paſſage of the blood through the *lungs* in men come to age, upon the ſame arguments? And with *Columbus*, a moſt skilfull and learned *Anatomiſt*, believe and aſſert the ſame from the ſtructure and largeneſs of the *lungs*; becauſe that the *arteria venoſa*, and likewiſe the *ventricle*, are alwayes full of blood, which muſt needs come hither out of the *veins*, by no other path, but through the *lungs*; as both he and we from our words before, our own eye-ſight, and other Arguments, do believe to be clear.

But ſeeing there are ſome ſuch perſons which admit of nothing, unleſs there be an authority alledged for it; let them know, that the very ſame truth may be proved from *Galens* own words, that is to ſay, not only that the blood may be transfuſed out of the *vena arterioſa*, into the *arteria venoſa*, and thence into the *left ventricle* of the *heart*, and afterwards tranſmitted into the *arteries*; but alſo that this is done by a continued pulſe of the *heart*, and motion of the *lungs*, whilſt we breath. There are in the *orifice* of the *vena arterioſa* three ſhuts, or doors, made like a Σ, or half-Moon, which altogether hinder the blood ſent into the *vena arterioſa* to return to the *heart*, which all know.

Galen

Galen expreſſes the uſe and neceſſity of thoſe ſhuts, in theſe words, *De uſu part.* 6. *Cap.* 10. *In all* (ſayes he) *there is a mutual Anaſtomoſis or opening of the veins, together with the arteries, in their kiſſing, and they borrow both blood and ſpirit from one another by inviſible and very narrow paſſages. But if the very mouth of the Vena Arterioſa had always ſtood open, and Nature had found no device to ſhut it; when it was requiſite, and to open it again, it could never have come to paſs that by thoſe inviſible and little kiſſes, the Thorax being contracted the blood could be transfuſed into the arteries. For every thing is not from any thing extracted and emitted after the ſame manner; for as that which is light is eaſilier attracted than that which is heavy, by dilatation of the inſtruments, and by the conſtriction is ſqueezed out again; ſo any thing is eaſier attracted through a broad paſſage, than through a narrow paſſage, and ſo ſent forth again. But when the Thorax is contracted, the Arteriæ venoſæ which are in the Lungs, being on every ſide pulſated, and compreſſ'd together ſtrongly, do ſqueeze out very quickly the ſpirit that is in them, and do borrow through thoſe fine touches a part of the blood, which truly could never come to paſs, if through that great opening, ſuch as is the Vena Arterioſa, the blood could return back to the Heart: Now the return of it through that great mouth being ſtop'd, ſome of it through thoſe ſmall orifices does drop into the Arteries, it being preſſ'd every way.* And a little after in the following Chapter, *how much the more the Thorax endeavors to ſqueez out the blood, ſo much the more thoſe Membranes, that is to ſay thoſe three Sigma like doors, do cloſlier ſhut the mouth of it, and ſuffer nothing to return.* Which he ſayes likewiſe in the ſame tenth Chapter a little before. *Unleſs there were doors there would follow a three-*

threefold inconvenience, for so the blood should make such a long journey but in vain, by flowing in the Diastoles of the Lungs, and filling all the veins in them, in the Systoles, as it were a neap tide, like Euripus *reciprocating its motion again and again, hither and thither, which would not be convenient for the blood: But this may seem no great matter, but that in the mean time it should weaken the benefit of respiration, this is no more to be counted a small business.* And a little after, *And likewise the third inconvenience would follow, no slight one, when in our breathing our blood should return backwards, unless our Maker had ordained the natural position of those Membranes.* Whence he concludes Chap. 2. *Indeed the use of all the shuts or portals is the same, to hinder the return of the matter; and either of them have a proper use to draw matter from the heart, that they may return no more, and to draw matters into the heart, that they may go no more from thence. For Nature would not have the heart to be wearied with needless travel, nor send thither whence it was better to extract, nor extract from thence again whither it was better to send. For which cause there being four orifices onely, two in either Ventricle, one takes in, the other draws forth.* And a little after. *Furthermore, when one of the vessels consisting but of one Tunicle is implanted into the Heart, and the other consisting of a double Tunicle is drawn forth from it, viz.* (The right ventricle *Galen* means, so do I the left ventricle by the same reason,) *It was needful that there should be as it were a cistern to both, to which both of them belonging, that the blood might be drawn out by one, and sent out by the other.*

That argument which *Galen* brings for the passages of the blood through the *right ventricle* out of the

the *vena cava* into the *lungs*, we may more rightly use for the passages of the blood out of the *veins* through the *heart* into the *arteries* changing only the terms.

It does therefore clearly appear from the words and places of *Galen*, a divine man, father of Physicians, both that the blood doth pass from the *vena arteriosa* into the little branches of the *arteria venosa*, both by reason of the pulse of the *heart* and also because of the motion of the *lungs* and *thorax*: See the commentarie of the most learned *Hofmannus* upon the sixth Book of *Galen de usu part.* which book I saw after I had written these things.

Furthermore it was necessary that the *heart* should receive the blood continually into the *ventricles*, as in a pond or cistern, and send it forth again: and for this reason it was necessary that it should be served with four locks or doors, whereof two should serve for the intromission and two for the emission of blood, lest either the blood like an *Euripus*, should inconveniently be driven up and down, or go back thither from whence it were fitter to be drawn, and flow from that part to which it was needful it should have been sent, and so should be wearied with idle travel, and the breathing of the *lungs* be hindred. Lastly our assertion appears clearly to be true, that the blood does continually and incessantly flow through the porosities of the *lungs*, out of the *right ventricle* into the *left*, out of the *vena cava* into the *arteria magna*; for seeing the blood is continually sent out of the *right ventricle* into the *lungs* through the *vena arteriosa*, and likewise is continually attracted out of the *lungs* into the *left*; which appears by

that

that which has been ſpoken, and the poſition of the Portals, it cannot be, but that it muſt needs paſs through continually.

And likewiſe ſeeing that always, and without intermiſſion, the blood enters into the *right ventricle* of the *heart*, and goes out, (which is likewiſe manifeſt, of the *left ventricle*, both by reaſon and ſenſe) it is impoſſible but that the blood ſhould paſs continually through, out of the *vena cava* into the *Aorta*.

That therefore which is apparent to be done in moſt, and really in all whilſt they are growing to age, by diſſection through moſt open paſſages, is here likewiſe manifeſt to come to paſs in thoſe when they are ariv'd to full age, by the hidden poroſities of the *lungs*, and touches of its veſſels both by *Galens* words, and that which has been ſpoken: From whence it appears, that albeit one *ventricle* of the heart, that is the *left*, were ſufficient for the deſpenſation of the blood through the whole body, and the eduction of it out of the *vena cava* (as it is in all creatures which want *lungs*;) Yet Nature deſiring that the blood ſhould be ſtrained through the *lungs*, was forc'd to add the *right ventricle*, by whoſe pulſe the blood ſhould be forc'd through the very *lungs* out of the *vena cava* into the receptacle of the *left ventricle*: and ſo it is to be ſaid that the *left ventricle* was made for the *lungs* ſake and not for nutrition only; ſeeing in ſuch an abundance of victual, adding to it the help of compulſion, it is no ways to be believed that the *lungs* ſhould rather want ſo much aliment, and that of blood ſo much more pure and full of ſpirit, as being immediately convey'd from the *ventricles* of the *heart*,

heart, then either the moſt pure ſubſtance of the *brain*, or the moſt reſplendent and divine conſtitution of the *eyes*, or the fleſh of the *heart* it ſelf, which is more fitly nouriſhed by the *vena coronalis*.

CHAP. VIII.

Of the abundance of blood paſſing through the Heart out of the veins into the arteries, and of the circular motion of the blood.

THus much of the tranſfuſion of the blood out of the *veins* into the *arteries*, and how it is diſpoſed of and tranſmitted by the pulſe of the *heart*, to ſome of which thoſe perchance that were heretofore moved by the reaſons of *Galen*, *Columbus*, and others, will yield; now as concerning the abundance and increaſe of this blood, which doth paſs through, thoſe things which remain to be ſpoken of, though they be very conſiderable, yet when I ſhall mention them, they are ſo new and unheard of, that not only I fear miſchief which may arrive to me from the envy of ſome perſons, but I likewiſe doubt that every man almoſt will be my enemy, ſo much does cuſtome and doctrine once received and deeply rooted (as if it were another Nature) prevail with every one, and the venerable reverence of antiquity enforces: Howſoever, my reſolution is now ſet down, my hope is in the candor of thoſe which love truth, and learned ſpirits. Truly when I

had often and seriously considered with my self, what great abundance there was, both by the dissection and living things, for experiments sake, and the opening of *arteries*, and many wayes of searching, and from the Symetrie, and magnitude of the *ventricles* of the *heart*, and of the vessels which go into it, and go out from it, (since Nature making nothing in vain, did not allot that greatness proportionably to no purpose, to those vessels) as likewise from the continued and carefull artifice of the *doors* and *fibers*, and the rest of the *fabrick*, and from many other things; and when I had a long time considered with my self how great abundance of blood was passed through, and in how short time that transmission was done, whether or no the juyce of the nourishment which we receive could furnish this or no: at last I perceived that the *veins* should be quite emptied, and the *arteries* on the other side be burst with too much intrusion of blood, unless the blood did pass back again by some way out of the *veins* into the *arteries*, and return into the *right ventricle* of the *heart*.

I began to bethink my self, if it might not have a *circular motion*, which afterwards I found true, and that the blood was thrust forth and driven out of the *heart* by the *arteries* into the habit of the body and all parts of it, by the beating of the *left ventricle* of the *heart*, as it is driven into the *lungs* through the *vena arteriosa* by the beating of the *right*, and that it does return through the little *veins* into the *vena cava*, and to the *right ear* of the *heart*, as likewise out of the *lungs* through the aforesaid *arteria venosa* to the *left ventricle*, as we said before.

Which

Which motion we may call *circular*, after the ſame manner that *Ariſtotle* ſays that the rain and the air do imitate the motion of the ſuperiour bodies. For the earth being wet, evaporates by the heat of the *Sun*, and the vapours being rais'd aloft are condens'd and deſcend in ſhowrs, and wet the ground, and by this means here are generated, likewiſe, tempeſts, and the beginnings of meteors, from the circular motion of the *Sun*, and his approach and removal.

So in all likelihood it comes to paſs in the body, that all the parts are nouriſhed, cheriſhed, and quickned with blood, which is warm, perfect, vapourous, full of ſpirit, and that I may ſo ſay, alimentative: in the parts the blood is refrigerated, coagulated, and made as it were barren, from thence it returns to the *heart*, as to the fountain or dwelling-houſe of the body, to recover its perfection, and there again by natural heat, powerfull, and vehement, it is melted, and is diſpens'd again through the body from thence, being fraught with ſpirits, as with balſam, and that all the things do depend upon the motional pulſation of the *heart*.

So the *heart* is the beginning of life, the *Sun* of the *Microcoſm*, as proportionably the *Sun* deſerves to be call'd the *heart* of the world, by whoſe vertue, and pulſation, the blood is mov'd, perfected, made vegetable, and is defended from corruption, and mattering; and this familiar houſhold-god doth his duty to the whole body, by nouriſhing, cheriſhing, and vegetating, being the foundation of life, and author of all. But we ſhall ſpeak more conveniently of theſe in

the ſpeculation of the final cauſe of this motion.

Hence it is, ſeeing the *veins* are certain wayes or veſſels carrying the blood, there are two ſorts of them, the *Cava* and *Aorta*. Not by reaſon of the ſide, as *Ariſtotle* ſays, but by their function; and not, as is commonly ſpoken, by their conſtitution, ſeeing in many Creatures (as I have ſaid) a *vein* differs not from an *arterie*, in the thickneſs of the Tunicle, but by their uſe and employment diſtinguiſhable, a *vein* and an *arterie*, both of them not undeſervedly called *veins* by the Antients, as *Galen* has obſerved, becauſe that this, *viz.* the *arterie*, is a way carrying the blood from the *heart* into the habit of the body, the other a way carrying it from the habit of the body back again into the *heart*. This is the way from the *heart*, the other the way to the *heart*. This contains blood rawiſh, unprofitable, and now made unfit for nutrition, the other blood digeſted, perfect, and alimentative.

CHAP.

CHAP. IX.

That there is a Circulation of the blood from the confirmation of the first supposition.

BUt leſt any ſhould think that we put a cheat upon them, and bring only fair aſſertions, without any ground, and innovate without a cauſe; there comes three things to be confirm'd, which being ſet down, I think this truth muſt needs follow, and be apparent to all men.

1. Firſt, That the blood is continually, and without any intermiſſion, tranſmitted out of the *vena cava* into the *arteries*, in ſo great abundance, that it cannot be recruited by thoſe things we take in, and inſomuch that the whole maſs of blood would quickly paſs through.

2. In the ſecond place, that continually, duely, and without ceaſe, the blood is driven into every member and part, and enters by the pulſe of the *arteries*, and that in far greater abundance then is neceſſary for nouriſhment, or then the whole maſs is able to furniſh.

3. And likewiſe thirdly, that the *veins* themſelves do perpetually bring back this blood into the manſion of the *heart*.

Theſe things being prov'd, I think it will appear that it doth go round, is returned, thruſt forward, and comes back from the *heart* into the extremities, and from thence into the *heart* again, and ſo makes as it were a circular motion.

Let us suppose how much blood the *left ventricle* contains in its *dilatation* when its full, either by our thought or experiment, either ℥ij, or ℥iij, or ℥j ſ., I have found in a dead man above ℥ij.

Let us suppose likewise, how much less in the contraction, or when it does contract it self, the *heart* may contain, and how much less capacious the *ventricle* is, and from thence how much blood is thrust out of the *arteria magna*: for in the *Systole* there is alwaies some thrust forth, which was demonstrated in the third Chapter, and all men acknowledge, being induced to believe it from the *fabrick* of the vessels, by a very probable conjecture we may averr that there is sent in of this into the *arterie* a fourth, or fifth, or sixth, at least an eigth, part. So let us imagine, that in a Man there is sent forth in every pulse of the *heart*, an ounce and a half, or three drams, or one dram of blood, which by reason of the hindrance of the portals cannot return to the *heart*.

The *heart* in one half hour makes above a thousand pulses, yea in some, and at some times, two, three or four thousand; now multiply the drams either a thousand times three drams, or two drams or five hundred ounces, or such a proportionate quantity of blood, transfus'd through the *heart* into the *arteries*, which is a greater quantity than is found in the whole body. So likewise in a Sheep or a Dog if there pass (I grant ye) but one scruple, in one half hour there passes a thousand scruples, or about three pounds and a half of blood: in whose body, for the most part is not contained above four pounds of blood, for I have tryed it in a Sheep.

So

So our account being almoſt layd, according to which we may gueſs the quantity of blood which is tranſmitted, counting the pulſations, it ſeems that the whole maſs of blood does paſs out of the *veins* into the *arteries* through the *heart*, and likewiſe through the *lungs*.

But grant that it be not done in half an hour, but in a whole hour, or in a day, be it as you will, it is manifeſt that more blood is continually tranſmitted through the *heart*, than either the food which we receive can furniſh, or is poſſible to be contained in the *veins*. Nor is it to be ſaid, that the *heart* in its contraction ſometimes does thruſt out, ſometimes not, or as much as nothing, or ſomething imaginary. This I refuted before, and beſides its againſt ſenſe or reaſon. For if in the dilatation of the *heart* it muſt needs come to paſs that the *ventricles* are filled with blood, it it likewiſe neceſſary that in its contraction it ſhould alwaies thurſt forth, and that not a little, ſeeing the conduits are not ſmall; and the protruſion not ſeldome: its very convenient likewiſe in every propulſion, the proportion of the blood thurſt out ſhould be a third part, or ſixth part, or eighth part in proportion to that which is before contain'd in the *ventricle*, and which did fill it in the dilatation, according as the proportion of the *ventricle* being contracted is to the proportion of it being incontracted; and as in the dilatation it nevercomes to paſs, that it is ever fill'd with nothing, or ſomething meerly imaginary, ſo in the contraction it never expells nothing, or that which is imaginary, but alwaies ſomething, according to the proportion of the contraction. Wherefore it is to be con-

cluded, that if in a Man, a Cow, or a Sheep, the *heart* doth ſend forth one dram, and that there be a thouſand pulſes in one half hour, that it ſhall come to paſs in the ſame time that there ſhall be ten pounds and five ounces tranſmitted, if at one pulſe it ſend forth two drams, twenty pound and ℥ 10, if half an ounce forty one pounds and ℥8, if an ounce, 83 ℔, and ℥4 will come to be transfuſ'd, I ſay, in half an hour, out of the *veins* into the *arteries*.

But it may perchance be that I ſhall ſet down here more acurately how much is thruſt out at every pulſation, when more, and when leſs, and for what reaſon, out of many obſervations which I have gathered.

In the mean time this I know and declare to all men, that ſometimes the blood paſſes in leſs, ſometimes in more abundant quantity, and the circuit of the blood is performed ſometimes ſooner, ſometimes ſlower, according to the age, temperature, external and internal cauſe, accidents natural or innatural, ſleep, reſt, food, exerciſe, paſſions of the mind, and the like.

But howſoever, though the blood paſs through the *heart* and *lungs*, in the leaſt quantity that may be, it is convey'd in far greater abundance into the *arteries*, and the whole body, than it is poſſible that it could be ſupplyed by juice of nouriſhment which we receive, unleſs there were a regreſs made by its circuition.

This likewiſe appears by our ſenſe, when we look upon the diſſection of living things, not only in the apertion of the great *arterie*, but (as *Galen* affirms in man himſelf) if any, yea the leaſt

arterie

arterie be cut, all the maſs of blood will be drain'd out of the whole body, as well out of the *veins* as out of the *arteries*, in the ſpace of half an hour.

Likewiſe Butchers can well witneſs this, when in killing of an oxe, they cut the jugular *arteries*, they drain the whole maſs of blood in leſs than a quarter of an hour, and empty all the veſſels, which we find likewiſe to come to paſs in cutting off members and tumours, by too much profuſion of blood, ſometimes in a little ſpace.

Nor does it weaken the force of this argument, that ſome will ſay, that in ſlaughter, or of cutting off members, the blood flows out as much through the *veins* as through the *arteries*, ſeeing the buſineſs is far otherwiſe. For the *veins*, becauſe they flap down, and that there is no out-driving force in them, and becauſe their compoſition is likewiſe with ſtoppages of portals, as hereafter ſhall appear, they ſhed but a very little, but the *arteries* pour out the blood more largely, impetuouſly, by impulſion, as if it were caſt out of a ſpout. But let the caſe be tryed omitting the *vein* and cutting the *jugular arterie* in a ſheep, or a Dog, it will be wonderful to ſee, with how great force, how great protruſion, how quickly, you ſhall ſee all the blood to be emptied from the whole body as well from the *veins* as from the *arteries*. But it is manifeſt by what we have ſaid, that the *arteries* receive blood no where elſe but from the *veins* by tranſmiſſion through the *heart*, wherefore tying the *aorta* at the root of the *heart*, and opening the *jugular* or any other *arterie*, if you ſee the *arteries* empty, and the *veins* only full, it is not to be wondred at.

Hence

Hence you shall plainly see the cause in *Anatomy* why so much blood is found in the *veins*, and but a little in the *arteries*, why there is a great deal found in the *right ventricle*, and but a little in the *left*, (which thing perchance gave occasion of doubt to the antients, and of believing, that spirits alone were contain'd in those concavities, whilst the animal was alive) the cause perchance is, because there is no passage afforded from the *veins* into the *arteries* but through the *lungs* and the *heart*, but when the *lungs* have expir'd and leave off to move, the blood is hindred to pass from the little branches of the *vena arteriosa* into the *arteria venosa*, and so into the *left ventricle* of the *heart* (as in an *Embryon* it was before observed, that it was stopt by reason of the want of motion of the *lungs*, which open and shut up the touches, and hidden and invisible porosities) but seeing the *heart* does not leave off motion at the same time with the *lungs* but does beat afterwards and outlive them, it comes to pass that the *left ventricle* and the *arteries* do send forth blood into the habit of the body, and not receiving it through the *lungs*, do therefore appear empty.

But this likewise affords no small credit to our purpose, since there can be no other cause given for this but what in our supposition we have alleged.

Besides from hence it is manifest, that how much the more, or more vehemently the *arteries* do beat it happens in all fluxes of blood that so much the sooner the whole body is emptied.

Hence

Hence likewiſe it comes to paſs, that in all faintings, all fear, and the like, when the *heart* beats more weakly, languiſhing, and with no force, that it happens that all fluxes of blood are ſtop'd and hindred.

Hence likewiſe it is that in a dead body, after the *heart* ceaſes to beat, you cannot out of the *jugular* or *crural veins* and opening of the *arteries* by any means extract above half the maſs of blood, nor can a butcher when he hath knockt the oxe on the head, and ſtund him, draw all the blood from him unleſs he cut his throat before the heart leaves beating.

Laſt of all, from hence we may imagine that no man hitherto has ſaid any thing aright concerning the *Anaſtomoſis*, where it is; how it is, and for what cauſe; I am now in that ſearch.

Chap.

CHAP. X.

The first ſuppoſition concerning the quantity of the blood which paſſes through from the veins into the arteries, and that there is a circulation of the blood is vindicated from objections, and further confirm'd by experiments.

THus far the firſt poſition is vindicated, whether the matter be to be reckoned by account, or whether we refer it to experiment, or our own eye-ſight, *viz.* that the blood continually paſſes out of the *veins* into the *arteries* in greater abundance then can be furniſhed by our nouriſhment, ſo that the whole maſs in a little time paſſing through that way, it muſt neceſſarily follow that there ſhould be a circulation, and that the blood ſhould return.

But if any here can ſay that it can paſs through in great abundance, and yet it is not needfull that there ſhould be a circulation, ſince it comes to be made up by what we receive, and that the encreaſe of milk in the paps may be an inſtance, for a Cow in one day gives three, four, or ſeven gallons, or more, a woman likewiſe gives two or three pints every day or more, in the nurſing of a child or two, which is manifeſt to be reſtor'd by what ſhe receives, it is to be anſwer'd, that the heart is known to ſend out ſo much in one hour or two.

But if not as yet ſatisfied he ſhall ſtill preſs further, and ſay, that although by the diſſecting of

of an *arterie*, and giving and opening a way, it comes to paſs beſides the courſe of Nature, that the blood is forcibly pour'd out, yet it does not therefore come to paſs in an entire body, no out-let being given, and the *arteries* being full, and conſtituted according to Nature, that ſuch a great quantity ſhould paſs in ſo ſhort ſpace, inſomuch that there muſt needs be a regreſs; It is to be anſwer'd, That by laying of an account it appears from former reckoning, that how much the *heart* being fill'd does contain more in its dilatation, then in its conſtriction, ſo much (for the moſt part) at every pulſation is ſent forth, and for that cauſe does there ſo much paſs the body being whole, and conſtituted according to Nature.

But in *Serpents*, and in ſome *Fiſhes*, binding the veins a little beneath the *heart*, you ſhall quickly ſee the diſtance betwixt the *heart* and the *ligature* to be emptied, ſo that you muſt needs affirm the recourſe of blood, unleſs you will deny your own *eye-ſight*. The ſame ſhall clearly appear afterwards in the confirmation of the ſecond ſuppoſition.

Let us conclude, confirming all theſe with one example, that every one may believe his own eyes: If any one cut up a live *Adder*, he ſhall ſee the *heart* beat calmly, diſtinctly, for a whole hour, and ſo contract it ſelf, (in its conſtriction being oblong) and thruſt it ſelf out again like a Worm. That it is whitiſh in the *Syſtole*, and contrary in the *Diaſtole*, together with all the reſt, by which I ſaid this truth was evidently confirmed, for here the parts are longer and

and more distinct. But this we may more especially find, and clearer then the noon-day.

The *vena cava* enters the lower part of the *heart*; the *arterie* comes out at the upper part, now taking hold of the *vena cava* with a pair of pinsers, or with your finger and thumb, and the course of the blood being stop'd a little way beneath the *heart*, you shall upon the pulse perceive to be presently almost emptied that place which is betwixt your fingers and the *heart*, the blood being exhausted by the pulse of the *heart*; and that the *heart* will be of a far whiter colour, and that it is lesser too in its dilatation for want of blood, and at last beats more faintly, insomuch that it seems in the end as it were to die; so soon again as you untie the *vein* both colour and bigness returns to the *heart*. Afterwards, if you do leave the *veins*, and do grasp or bind the *arterie* a little way from the *heart*, you shall on the contrary see them swell vehemently there where they are grasp'd, and that the *heart* is swell'd beyond measure, and does acquire a purple colour till it be blackish again, and that it is at last oppress with blood so that you would think it would be suffocated, but untying the string, that it does return to its natural constitution, colour, and bigness.

So now there are two sorts of death, extinction, by reason of defect; and suffocation, by too great quantity: here you may have the Example of both before your eyes, and confirm the truth which hath been spoken concerning the *heart*, by your own view.

CHAP.

CHAP. XI.

The ſecond ſuppoſition is confirmed.

THe ſecond is to be confirm'd by us, which that it may appear the clearer to our view, ſome experiments are to be taken notice of, by which it is clear, that the blood doth enter into every member through the *arteries*, and does return by the *veins*, and that the *arteries* are the veſſels carrying the blood from the *heart*, and that the *veins* are the veſſels and wayes by which the blood is returned to the *heart* it ſelf; and that the blood in the members and extremities does paſs from the *arteries* into the *veins* (either mediately by an *Anaſtomoſis*, or immediately through the poroſities of the *fleſh*, or both wayes,) as before it did in the *heart* and *thorax* out of the *veins*, into the *arteries*: whence it is manifeſt, that in its *circulation* it moves from thence hither, and from hence thither, to wit, from the *centre* to the *extremities*, and from the *extremities* again to the *centre*.

But likewiſe computation being afterwards made, it appears in the ſame place, that in regard of the abundance it can neither be recruited by that which we take in, nor is there ſo much requir'd for nouriſhment. As likewiſe concerning *ligatures* it is clear how they attract, that they do it not either by heat, nor grief, or force of *vacuum*, nor any other cauſe known heretofore. As likewiſe what convenience and uſe *ligatures* do bring to Phyſick, how they ſtop, or provoke the flux of blood, and how they cauſe *gangrenes*, and mortifications of the mem-

members, and by this means how they are of use in the gelding of some creatures, and in taking away of *fleshy tumors*, and *wens*. For certainly from hence it comes to pass, that none have rightly understood the causes, and reasons of all these things, though all almost according to the opinion of the Antients, do propound and give their verdict for *ligatures* in diseases, yet few in the administration of them do afford any help by them in their cures.

Some *ligatures* are *strict*; others of a *middle sort*.

A *strict ligature* I call such a one, where the arm is so streightly bound with the *band* or rope, that you cannot perceive the *arterie* to beat any where beyond the *ligature*; such a one we use in the cutting off of members, taking a care of the flux of blood in gelding of *animals*, taking away of *tumors*: by which *ligature* the afflux of aliment and heat being altogether intercepted, the vessels, the testicles, fade and dy, and the great *tumors* of flesh, and afterwards fall quite away.

That I call a *middle sort* of *ligature*; which does compress the member every way, but without pain, insomuch that it suffers the *arterie* to beat a little beyond the *ligature*; such a one as is used in the attraction and emission of blood: for albeit you make the *ligature* above the elbow, yet you shall perceive the *arteries* to beat a little in the wrist if you touch it, if in the blood-letting the *ligature* be made aright.

Now let there be an experiment made in a mans arm, either taking a band, such as they use in blood letting, or by the stronger grasp of the hand it self, which indeed is most conveniently done

done in a lean body which has larger *veins*; and when the body being heated, the extremities are warm, and a greater quantity of blood is in the extremities, and more vehement pulsations, for then all things will more evidently appear.

If you do make then a hard ligature, drawing it as streight as any can endure it, you may first observe that beyond that *ligature* the *arterie* does not beat in the *wrist*, nor any where else, and then that immediately the *arterie* begins above the *ligature*, has its *Diastole* higher, and beats more vehemently, and does as it were with a kind of tide rise towards the *ligature* (as if it did endeavour to beat through and open its flux which is intercepted) and the passage which is stopt, and that it does appear to be fuller there then is convenient. In the mean time the hand retains its colour and constitution, only in process of time it begins to be a little coldish, but nothing is attracted into it.

After that this ligature has continued a while, and that in a sudden it is a little untied into a middle sort, such I say as they use in letting of blood, it is to be observed that the whole hand is streightwayes imbued with colour, and distended, and that the *veins* of it become swell'd and lumpie, and that in the space of ten or twelve pulses the blood being thrust forward and cast into the hand is seen to be extreme full, and that a great quantity of blood is quickly drawn by the *ligature*, without either anguish, heat, or shunning of the *vacuum*, or any other cause heretofore mentioned.

In the mean time, if any one put his finger to

the *arterie*, in the very time of the unbinding, near to the *ligature*, he ſhall feel the blood as it were paſſing by under his finger.

Moreover he in whoſe arm the experiment is made, upon the change of a *ſtreight ligature* into a *middle one* (the impediment being as it were removed) he ſhall plainly feel the heat and blood enter by pulſation, and perceive ſomething to be breathed by the conduct of the *arterie* as it were immediately, and to be diſperſed over all his hand, and that his hand is preſently heated and diſtended. As in a *ſtrict ligature* the *arteries* above are diſtended, and do beat, and not below, and the *veins* become leſſer, ſo in the *middle ſort* of *ligature* the *veins* ſwell, and become ſtubborn, but not above, and the *arteries* become leſs, nay if you ſqueeze the *veins*, unleſs you do it very ſtrongly, hardly ſhall you ſee the blood paſs above the *ligature*, or the *veins* fall.

So from theſe things it is eaſie for any man that will diligently obſerve, to know that the blood does enter by the *arteries*, for by their *ſtrict ligature* nothing is attracted, the hand retains its colour, nor happens there any diſtenſion, but being a little untied as in the *middle* or *gentle ligature*, it is manifeſt that the hand is ſwell'd, and that the blood by the force and impulſion is abundantly thruſt in. Where the blood flows forth as in the *gentle ligature* they beat, where it does not flow they beat not at all. In the mean time the *veins* being ſtreightned nothing can flow through them, of which this is a token, that beneath the *ligature*

gature they become much more ſwell'd, then above, and then they uſe to be when the *ligature* is taken away, hence it is clearly manifeſt, that the *ligature* hinders the return of the blood through the *veins* into the ſuperiour parts, and makes thoſe beneath the *ligature* continue ſwell'd.

But the *arteries* in this caſe do thruſt out the blood beyond the *ligatures* from the inward parts by the ſtrength and impulſion of the *heart*, notwithſtanding the *gentle ligature*. This is the difference of the *ſtrict ligature* from the *gentle* one, that the *ſtrict ligature* does not only intercept the paſſage of the blood in the *veins* but in the *arteries* alſo, that which is *gentle* doth not hinder the pulſifick vertue, but that it ſtretches it ſelf and drives out the blood into the furtheſt parts of the body.

So that we may reaſon thus; when in a *gentle ligature* we ſee the *veins* ſwell'd and diſtended, and the hand to be very full of blood, whence comes this? For either the blood comes through the *veins*, or through the *arteries* beneath the *ligature*, or through the hidden pores; Out of the *veins* it cannot, by hidden paſſages leſs, therefore needs muſt it by the *arteries*, as we have ſaid. That it cannot by the *veins* is apparent, when the blood cannot be ſqueezed back above the *ligature*, unleſs you take the *ligature* quite away: Then you may ſee the *veins* fall and diſburthen themſelves into the upper parts, and the hand grow white, and all the formerly gathered ſwelling and blood to vaniſh apace. He him-

ſelf will better perceive it, whoſe body or arm has been ſo bound a good while, and his hands by that means become ſwell'd, and made colder, I ſay, he ſhall feel ſomewhat that is cold to creep up to his elbow or armpits, to wit, with the return of the blood, which return of cold blood to the *heart* after blood-letting, after the untying of the band, I did imagine to be the cauſe of fainting, which we likewiſe ſee come to paſs in ſtrong men, and moſt after the untying of the *ligature*, which commonly they ſay comes to paſs from the turning of the blood. Beſides, when preſently upon the untying of the *ſtrict ligature* into a *gentle* one, we ſee, that by the immiſſion of blood through the *arteries*, the *veins* comprehended beneath the *ligature* do ſwell up, and not the *arteries*, it is a ſign that the blood does paſs out of the *arteries* into the *veins*, and not on the contrary; and that there is an *Anaſtomoſis* of the veſſels, or that the pores of the fleſh and ſolid parts are pervious to the blood. It is likewiſe a ſign that very many *veins* do communicate together, when a gentle *ligature* being made about the arm many of them do ſwell together, but paſſage being open'd out of one little *vein* with the *Lancett*, they ſtreightwayes fall all of them, and disburthening themſelves all into that one, do almoſt all flap down.

From hence may every body know the cauſe of attraction which is made by *ligature*, and perchance of all fluxes, *viz.* as in the hands, when the *veins* are drawn together by that *ligature*

gature which I call *gentle*, the blood cannot go forth; in the mean time if it be driven violently through the *arteries*, that is to say, by the force of the *heart*, of neceſſity the part muſt be fill'd and diſtended.

For otherwiſe how could it be? for *heat*, *anguiſh*, and *force* of the *vacuum* do indeed attract, but ſo as the part may be full, not that it ſhould be diſtended, and ſwoln beyond its natural conſtitution. But for the in-thruſting, and ſtraight in-driving of the blood, it is neither to be believ'd nor can it be demonſtrated a member can be ſuddenly oppreſs'd, the fleſh ſuffer a ſolution of its *continuum*, and the veſſels be ſeen to burſt, that this can either be done by *anguiſh*, *heat*, or *force* of the *vacuum*.

Moreover it ſo falls out, that there is an attraction made by the *ligature*, without all *grief*, *heat*, or *force* of the *vacuum*. But if by any *anguiſh* the blood ſhould chance to be attracted, which way ſhould, beneath the *ligature*, the hands, and the fingers, and the *veins* ſwell, and become ſwell'd, the arm being tyed at the elbow, ſeeing that by reaſon of the compreſſion of the *ligature* the blood could not come thither through the *veins*? and why ſhould there no ſign appear above the *ligature* either of *tumour* or *repletion*, neither any ſign of attraction or a flux at all?

But this is the manifeſt cauſe of attraction beneath the *ligature*, and of ſwelling beyond meaſure in the hand and fingers, to wit, that the blood does enter forcibly and apace, but cannot get out again.

Hence is all the cauſe of *tumour*, and of all oppreſſive redundancy in any part; becauſe the wayes of ingreſs are open, and the wayes of regreſs ſhut: hence it muſt needs follow, that the *humour* ſhould abound, and the part be raiſed with ſwelling.

Whether may it not be from hence hat in ſwellings which are inflam'd, ſo long as the ſwelling receives increaſe, and is not in its higheſt eſtate, there is a full pulſe felt in that place, eſpecially in hotter *tumours*, in which the increaſe uſes to be on a ſudden, ſhall be for our after-ſearch; as likewiſe whether that happens from hence, (which by chance I had experience of in my ſelf) I falling out of a Coach, and being ſomewhat hurt in my fore-head, there where the little branch of the *arterie* creeps out of the temples, I felt a ſwelling about the bigneſs of an egg in the ſpace of twenty pulſes, without either heat or much pain, *viz.* becauſe of the nearneſs of the *arterie*, the blood was abundantly and more ſwiftly driven into the bruis'd place.

Hence does it appear for what cauſe in *Phlebotomie* when we would have the blood leap out further and with greater force, we bind it above the cutting of the *vein*, not below; but if it flow in ſo great quantity through the *veins* from the ſuperiour parts, that *ligature* would not only not help, but hinder: for it were more likely that it ſhould be bound below, that the blood being hinder'd might go out more abundantly if it did flow thither, and deſcend from the upper parts into

into the *veins*. But ſince from ſomewhere elſe, it is driven by the *arteries* into the lower *veins*, in which regreſs by reaſon of the *ligature* is hindred, the *veins* ſwell and can ſqueeze it out, and throw it further through the *orifice*, but ſee, the *ligature* being unty'd, and the way of egreſs being open, the blood doth no longer come, but drop by drop, and that which every body knows, If in *Phlebotomy* you either untie the band, or bind it below, or bind the member with too *ſtrict* a *ligature* it comes not forth, as if all force were taken from it, becauſe forſooth the way of entrance and influx of blood through the *arteries* is by that ſtrict *ligature* intercepted, or a more free regreſs is granted through the *veins*, the *ligature* being untied.

CHAP. XII.

That there is a circulation of the blood, from the confirmation of the second supposition.

SEeing these things are so, it is certain that another thing which I said before is likewise confirm'd; that the blood does continually pass through the *heart*. For we see in the habit of the body, that the blood flows continually out of the *arteries* into the *veins*, not out of the *veins* into the *arteries*: We see moreover, that from one arm the whole mass of blood may be exhausted, and that too by opening but one cuticular *vein* with a lance, if the ligature be handsomely made: We see besides, that it is powred out so forcibly and so abundantly, that it is certain that not only that which was comprehended in the arm beneath the *ligature*, before the section, is quickly and in a little time evacuated, but likewise the blood out of the whole body, as well the *veins* as the *arteries*.

Wherefore we must confess first that by strength and force it is furnished, and by force it is driven beyond the *ligature* (for with force it goes out, and therefore by the strength and pulse of the *heart*) for the force and impulsion of the blood is only from the *heart*.

Next, that this flux comes from the *heart*, and that

that it flows by a paſſage made through the *heart* out of the great *veins*, ſeeing below the *ligature* the blood enters by the *arteries*, not by the *veins*, and the *arteries* at no time receive blood out of the *veins*, unleſs it be out of the *left ventricle* of the *heart*. Nor could there any otherwiſe ſo great abundance be exhauſted out of one *vein*, making a *ligature* above, eſpecially ſo forcibly, ſo abundantly, ſo eaſily, ſo ſuddenly, unleſs the conſequents were atchieved by the force and impulſion of the *heart*, as is ſaid.

And if theſe things be ſo, we may very openly make a computation of the quantity, and argue concerning the motion of blood. For if any one (the blood breaking out according to its uſual effuſion and force) ſuffer it to come ſo for half an hour, no body needs doubt but that the greateſt part of it being exhauſted, faintings and ſoundings would follow, and not only the *arteries*, but the greateſt *veins* would be likewiſe emptied: Therefore it ſtands with reaſon, that in the ſpace of that half hour there paſſes ſo much out of the great *vein* through the *heart* into the *aorta*. Further, if you ſhould reckon how many ounces flow through one arm, or how many ounces are thruſt within the *gentle ligature* in 20 or 30 pulſations, truly it would minister occaſion of thinking how much may paſs through the other arm, both the leggs, and both the *coluſes*, and through all the other *arteries* and *veins* of the body: and that the flux which is made through the *lungs* and the *ventricles* of the *heart*, muſt continually furniſh of neceſſity new blood, and ſo make a circuit about the

the *veins*, since so great a quantity cannot be furnished from those things we eat, and that it is far greater than is convenient for the nutrion of the parts.

It is to be observ'd further, that in the administration of *Phlebotomie* this truth chances sometime to be confirm'd; for though you tie the right arm, and lance it as it should be with a convenient *orifice* and administer all things as they ought to be, Yet if fear, or any other cause, or sounding do intervene through passion of the mind, so that the *heart* do beat more faintly, the blood will by no means pass through but drop after drop, especially if the *ligature* be made a little streighter. The reason is, because the pulse being but faint, and the outdriving force being but weak, the enfeebled part is not able to open the passage and thrust out the blood beyond the *ligature*, yea nor to draw it through the *lungs*, or to remove it plentifully out of the *veins* into the *arteries*. So after the same manner does it come to pass that *Womens flowers* and all other fluxes of blood are stop'd. This likewise appears by the contrary, for fear being remov'd, and the spirit recollected, when they do return to themselves, the *pulsifick strength* being now increased, you shall streightway see the *arteries* beat more vehemently in that part where they are bound, and move in the *wrist*, and the blood leap out farther through the *orifice*.

CHAP.

CHAP. XIII.

The third ſuppoſition is confirm'd, and that there is a circulation of the blood from the third ſuppoſition.

HItherto concerning the quantity of blood which paſſes through the *lungs* and *heart* in the centre of the body, and likewiſe from the *arteries* into the *veins* and habit of the body; It remains that we do explain which way the blood flowes back from the extremities through the *veins* into the *heart* and how the *veins* are the veſſels that carry it from the extremities to the centre, by which means we think thoſe three grounds propounded will be true, clear, firm, and ſufficient to gain credit.

But this ſhall be plain enough from the *portals* which are found in the concavities of the *veins*, their uſe, and from ocular experiments.

The moſt famous *Hieron. Fabr. ab aqua pend.* a moſt learned Anatomiſt, and a venerable old man, or as the moſt learned *Riolanus* would have it, *Jac. Silvius* did firſt of any delineate the membranal *portals* in the *veins* being in the figure of a Σ, or ſemilunarie, the moſt eminent and thinneſt parts of the inward tunicles of the *veins*: Their ſituation is in diſtant places, after a various manner, in diverſe perſons they are connate at the ſides of the *veins*, looking upwards towards the roots

roots of them, and in the middle capacity both of them (for they are for the moſt part two) looking towards one another, equally and duly touching one another, inſomuch that they are apt to ſtick together at the extremities, and to be joynd; and leſt they ſhould hinder any thing to return from the roots of the *veins* into the little branches, or from the greater into the leſs, they are ſo plac't that the horns of the hindermoſt are ſtretched towards the middles of the body of it which is before, and ſo interchangeable.

The finder out of theſe *portals* did not underſtand the uſe of them, nor others who have ſaid leſt the blood by its weight ſhould fall downward: for there are in the *jugular vein* thoſe that look downwards and do hinder the blood to be carried upwards. I (as likewiſe others) have found in the *emulgent veins* and branches of the *Meſenterie*, thoſe which did look towards the *vena cava*, and *vena porta*; add to this moreover that there are no ſuch in the *arteries*, and it is to be obſerv'd that dogs and cattle have all their *portals* in the dividing of the *crural veins* at the beginning of the *os ſacrum*, or in the *Iliac* branches near the *Coxendix*, in which there is no ſuch thing to be feared by reaſon of the upright ſtature in man. Nor are their *portals* in the *jugulars*, as others ſay, for fear of *Apoplexie*, becauſe the matter is apt in ſleep to flow into the head through the *ſopral arteries*.

Nor that the blood may ſtand ſtill in *divaricatione*, and that the whole blood ſhould not break in into the ſmall branches or thoſe which are more capacious: for they are likewiſe plac'd where

where there are no *divarications* though I confeſs they are more frequent where *divarications* are.

Nor that the motion of the blood may be retarded from the centre of the body; for it is likely that it is thruſt in leiſurely enough of its own accord, out of the greater into the leſſer branches, and ſo that it is ſeparated from the maſs and fountain: But the Portals were meerly made, leſt the blood ſhould move from the *greater veins* into the *leſſer* and tear or ſwell them; and that it ſhould not go from the centre of the body to the extremities, but rather from the extremities to the centre. Therefore by this motion the *ſmall Portals* are eaſily ſhut; and hinder any thing which is contrary to them; for they are ſo plac'd and ordain'd, that if any thing ſhould not be ſufficiently hindred in the paſſage by the *hornes* of the formoſt, but ſhould eſcape as it were through a chinck, the convexity or vault of the next might receive it, and ſo hinder it from paſſing any further.

I have often tryed that in diſſection if beginning at the roots of the *veins* I did put in the *Probe* towards the ſmall branches with all the skill I could, that it could not be further driven by reaſon of the hinderance of the *Portals*: On the contrary, if I did put it in outwardly from the branches towards the root, it paſſed very eaſily. In many places two *Portals* are ſo interchangeably plac'd and fitted, that when they are elevated in the middle of the concavity of the *vein*, they cloſe with one another to a hairs bredth, and in their extremities and convexities are united interchangeably that you can neither ſee with your eye-

eye-ſight nor any way diſcern any crevice or conjunction: on the contrary from outwardly putting in a *Probe* they eaſily give way (and like thoſe gates or fluces by which the courſe of rivers is ſtopt) they are eaſily turn'd back to intercept the motion of the blood from the *vena cava* and the *heart*, and being cloſely lifted up in many places whilſt they are interchangeably ſhut they do quite hinder and ſuppreſs, nor by any means ſuffer the blood to move neither upwards to the head nor downwards to the feet, nor to the ſides or arms, but do ſtop and reſiſt all manner of motion of the blood, which is begun in the *greater veins* and ends in the *leſſer*, yet do obey any which is begun by the *ſmall veins* and ends in the *greater*, and does provide a free and open way for it.

But that this truth may the more clearly appear, let the arm of a man alive be tyed above the Elbow, as if it were to let blood, A A will appear at diſtance eſpecially in country people and thoſe who are ſwoln vein'd, like little nodes or ſwellings: And B C D E F not only where the *divarication* is E F, but likewiſe where there is none C D, and theſe nodes are made by the *portals*. They thus appearing in the inſide of the hand or cubit, if you draw down the blood with your thumb or finger from the node O to H in the ſecond figure, you ſhall ſee that none can follow (the *portal* quite hindring it) and that the part of the *vein* H O of the ſecond figure, drawn down betwixt the ſwelling and the finger, is quite obliterated, and yet full enough above the knot or *portal* O H: Nay if you do retain the blood ſo drove

drove down and the blood emptied H, and do preſs downward with tother hand the upper part of the *vein* O, in the third figure, being full you ſhall find that by no means it can be forc'd or driven beyond the *portal* O; But how much the more you do indeavour to do this, ſo much the more ſhall you ſee at the *portal* or ſwelling of O, of the third, the *vein* ſwoln and diſtended, and yet that H O of the third figure is empty below.

Hence, ſince a man may make experiment in many places, it appears that the function of the *portal* in the *veins* is the ſame as that of the *Sigmoides*, or three pointed *portals*, which are made in the *orifice* of the *aorta* or *vena arterioſa*, to wit that they may be cloſely ſhut up, leſt they ſhould hinder the blood to return back again.

Beſides tying the arm again as before A A, and the *veins* ſwelling, if you hold the *vein* below any ſwelling or *portal* at any diſtance L of the fourth and afterwards with your finger M drive the blood upwards above the *portal* N, you ſhall ſee that part of the *vein* L N to remain empty, and that it cannot return by reaſon of the *portal* H O 2. but taking away your finger H 3. or L in the fourth figure, you ſhall ſee't again fill'd by the lower *veins*, and be like D C of the 1. ſo that from hence it appears plainly, that the blood does move towards the upper parts and the *heart* in the *veins*, and not on the contrary; and albeit in ſome places which are not cloſely ſhut, or where there is but one *portal*, the paſſage of the blood from the centre ſeems not to be quite hindred, yet for the moſt part it appears ſo, or at leaſt that which is negligently perform'd in

ſome

ſome places is recompens'd by the *portals*, in order following, either through their number, diligence or ſome other way, inſomuch as the *veins* are the open and patent wayes of returning the blood to the *heart*, but quite ſtop'd in its going out from thence.

This is moreover to be obſerv'd, tying the arm as before, and the *veins* ſwelling, and nodes or *Portals* appearing, if below any *Portal* in any place where you find the next you place your finger, which may hold the *vein*, that no blood may go from your hand upwards, then ſqueeze with your finger the blood from that part of the *vein* L N above the *Portal* as was ſaid before, then taking away your finger L ſuffer it to be fill'd up by thoſe under, as D C, and then preſſing again with your thumb in the ſame place, ſqueeze out of the blood L N and H O, and do this a thouſand times in a little ſpace.

Now if you reckon the buſineſs, how much by one compreſſion moves upwards by ſuppreſſion of the *portal*, and multiplying that by thouſands, you ſhall find ſo much blood paſs'd by this means through a little part of a *vein*, that you will find your ſelf perfectly perſwaded concerning the circulation of the blood, and of its ſwift motion.

But leſt you ſhould ſay, that by this means Nature is forc'd, if you do this in *portals* far diſtant, and do obſerve, taking away your thumb, how ſoon, and how ſwiftly the blood returns and fills the lower part of the *vein*, I do not doubt but you will find the very ſame.

CHAP.

CHAP. XIV.

The Concluſion of the demonſtration of the circulation of the blood.

NOw then in the laſt place we may bring our opinion, concerning *the circulation of the blood*, and propound it to all men.

Seeing it is confirmed by *reaſons* and *ocular experiments*, that the blood does paſs through the *lungs* and *heart* by the pulſe of the *ventricles*, and is driven in and ſent into the whole body, and does creep into the *veins* and poroſities of the fleſh, and through them returns from the little *veins* into the greater, from the circumference to the centre, from whence it comes at laſt into the *vena cava*, and into the *ear* of the *heart* in ſo great abundance, with ſo great flux, and reflux, from hence through the *arteries* thither, from thence through the *veins* hither back again, ſo that it cannot be furniſhed by thoſe things which we do take in, and in a far greater abundance than is competent for nouriſhment: It muſt be of neceſſity concluded that the blood is driven into a round by a *circular motion* in creatures, and that it moves perpetually; and hence does ariſe the action and function of the *heart*, which by pulſation it performs; and laſtly, that the motion and pulſation of the *heart* is the only cauſe.

CHAP. XV.

The circulation of the blood is confirmed by probable reasons.

BUt it will not be amiss likewise to add this, that according to some common reasons it is convenient, and it ought to be so. First (*Arist. de respir. & lib.* 2, 3. *of the parts of creatures*) seeing death is a corruption which befalls by reason of the defect of heat, and all things which are hot being alive, are cold when they dye, there must needs be a place and beginning of heat, (as it were a Fire, and dwelling house) by which the nursery of Nature, and the first beginnings of inbred fire may be contained and preserved; from whence heat and life may flow, as from their beginnings, into all parts; whither the aliment of it should come, and on which all *nutrition* and *vegetation* should depend.

And that this place is the *heart*, from whence is the beginning of life, I would have no body to doubt.

There is therefore a motion required to the blood, and such a one as that it may return again to the *heart*; for being sent far away into the outward parts of the body (as *Arist.* 2. *part. de Anim.*) from its own fountain, it would congeal and be immoveable. (For we do see, that by *motion*, *heat* and *spirit* is ingender'd, and preserv'd in

in all things, and by want of it vaniſhes.) Seeing therefore, that the blood ſtaying in the outward parts is congealed by the cold of the extremities, and of the ambient air, and is deſtitute of *ſpirits*, as it is in dead things, it was needful it ſhould reſume and redintegrate, by its return again, as well heats, as ſpirit, and indeed its own preſervation, from its own fountain and beginning.

We ſee, that by the exteriour cold, the extremities are ſometimes chill, inſomuch as noſe, hands, and cheeks, do look blew, like thoſe of dead men, becauſe that the blood ſtands ſtill in them, (as it does in carkaſſes in thoſe parts which are down tending,) whence it comes, that the members are nummed, and hardly moveable, ſo that they ſeem quite almoſt to have loſt life. They could certainly by no means (eſpecially ſo ſoon) recover heat, and colour, and life, unleſs they were by a new original, a Flux, and appulſion of heat, again cheriſhed. For how can they attract in whom heat and life are almoſt extinct? or thoſe that have their paſſages condenſed and ſtopt with congealed blood, how could they receive the coming nouriſhment and blood unleſs they did diſmiſs that which they before contained, and unleſs the *heart* were really that beginning from whence heat and life (as *Ariſt. reſpirat.* 2.) and from whence new blood being paſſed through the *arteries* imbued with ſpirit, that which is enfeebled and chilled might be driven out, and all the parts might redintegrate their languiſhing heat and vital nouriſhment almoſt extinct?

Hence it is that it may come to paſs, that the

heart being untouch't, life may be reſtored to the reſt of the parts, and ſoundneſs recovered; but the *heart* being refrigerated or affected with ſome heavy diſeaſe, the whole *animal* muſt needs ſuffer, and fall to corruption. When the beginning is corrupted, (as *Ariſt.* 3. *de part. Anim.*) there is nothing which can afford help to it, or thoſe things which do depend upon it.

And hence perchance the reaſon may be drawn, why in thoſe that with grief, love, cares, and the like are poſſeſſed, a conſumption or continuation happens, or cacochymie, or abundance of crudities, which cauſe all diſeaſes and kill men. For every paſſion of the mind which troubles mens ſpirits, either with grief, joy, hope, or anxiety, and gets acceſs to the *heart*, there makes it to change from its natural conſtitution, by diſtemperature, pulſation, and the reſt, that infecting all the nouriſhment, and weakning the ſtrength, it ought not at all to ſeem wonderful if it afterwards beget divers ſorts of incurable diſeaſes, in the members, and in the body, ſeeing the whole body in that caſe is afflicted by the corruption of the nouriſhment, and defect of the native warmth.

Beſides all this, ſeeing all creatures live by nouriſhment inwardly concocted, it is neceſſary that the concoction and diſtribution be perfect, and for that cauſe the place and receptacle where the nouriſhment is perfected, and from whence it is derived to every member. But this place is the *heart*, ſince it alone of all the parts (though it has for its private uſe the *coronal vein* and *arterie*) does contain in its concavities, as in ciſterns, or a celler, (to wit *ears* or *ventricles*) blood for the pub-

lick

lick uſe of the body; but the reſt of the parts have it only in veſſels for their own behoof, and for private uſe. Beſides, the *heart* only is ſo placed and appointed, that from thence by its pulſe it may equally diſtribute and diſpence (and that according to meaſure, and the concavities of the *arteries*, which are to ſupply every part) to thoſe which want, and deal it after this manner, as out of a treaſure and fountain. Moreover to this diſtribution and motion of the *blood*, violence, and an impulſor is required, ſuch as the *heart* is. To this add, that the blood does eaſily concentricate, and joyn of its own accord, to its beginning, as a part to the whole, or as a drop of water ſpilt upon the table to the whole maſs, as it does very ſwiftly, for ſlender cauſes, ſuch as are *cold*, *fear*, *horror*, and the like. Beſides, it is ſqueezed out of the *capular veins* into the *little branches*, and from thence into the greater, by the motion of the members, and *muſcles*: Likewiſe the blood is apter to move from the circumference to the centre, than otherwiſe though the *portals* did not hinder. From whence it follows, that if it do leave its beginning, and move againſt its will, and enter into places narrower, and colder, that it has need of violence and an impulſer, ſuch is the *heart* only, as we ſaid but now.

CHAP. XVI.

The circulation of the blood is proved by conſequence.

THere are likewiſe Queſtions, which from this ſuppoſed verity, for creating of belief, as arguments *à poſteriore*, are not altogether unuſeful. Theſe though they be envelop'd in much doubtfulneſs and obſcurity, yet eaſily admit of the aſſignation of cauſes and reaſons.

We ſee in contagion, in poiſoned wounds, or in the bitings of *Serpents*, or *mad doggs*, in the *French Pox*, and the like, that the part touched being not hurt, it ſo falls out that the whole habit of the body is vitiated. The *French Pox* ſometimes bewrays it ſelf by the pain of the head, or the ſhoulders, or other Symptoms, the genitals having no hurt at all. The wound made by the biting of a *mad dogg* being cured, we have notwithſtanding obſerved, that a *feaver*, and other horrible Symptoms have enſued: Becauſe the contagion being imprinted into the part, it appears, that it is from hence carried to the *heart* with the blood returning, and can afterwards infect the whole body. In the beginning of a *tertian feaver* the morbifick, cauſe going to the *heart* makes them breathleſs, ſighing, and lazie, becauſe the vital beginning is oppreſſed, and the blood is driven againſt the *lungs*, and thickned, and finds no paſ-

ſage

ſage (I ſpeak this, having had experience from the diſſection of them that have dyed in the beginning of the acceſſion) then the pulſations are always frequent, little, and ſometimes diſorderly: But the heat being increaſed, and the matter obtenuated, the wayes being open, and paſſages made, the whole body grows hot, the pulſes become greater and more vehement, the Paroxiſm of the *feaver* growing higer, to wit, the preternatural heat being kindled in the *heart*, is diffus'd from thence by the *arteries* into the whole body, together with the morbifick matter, which by this means is overcome and diſſolved by nature.

Likewiſe, ſeeing medicaments outwardly applied, ever uſe their force within, as if they were taken outwardly; (*Coloquintida* and *Aloes* looſen the belly; *Garlick* applyed to the ſoles of the feet, cauſes *expectoration*; *Cantharides* move urine, and cordials do corroborate, and infinite of this kind.) From hence it is conſtantly averred, perchance not without cauſe, that the *veins*, through their *orifices*, draw a little of thoſe things which are outwardly applyed, and carry it in with the blood, after the ſame manner as thoſe in the *Meſenterie* do ſuck the *Chylus* out of the *inteſtines*, and carry it to the *liver*, together with the blood.

In the *Meſenterie* likewiſe, the blood entering into the *Cœliac arterie*, the upper and neather *Meſenteries*, goes forward to the *inteſtines*; by which, together with the *Chylus* attracted by the *veins*, it returns through the many branches of them into the *Porta* of the *liver*, and through it in-

to the *vena cava*; ſo it comes to paſs, that the blood in theſe *veins* is imbued with the ſame colour and conſiſtence, as in the reſt, otherwiſe than many believe: for we muſt needs believe, that it very fitly and probably comes to paſs, in the ſtem or branch of the *capular veins*, that there are two motions, one of the *Chylus* upwards, another of the blood downwards; but is not this done by a main providence of nature? for if the raw *Chylus* ſhould be mixed with the concocted blood in equal proportions, no concoction, tranſmutation, or ſanguification ſhould from thence ariſe: But rather ſince they are interchangeably active and paſſive, from the union of them being altered, there ſhould ariſe a mixture, and a thing of a middle nature betwixt the two; as in the mixing of wine and water, there is begotten a wine-foyl: But now, when with the great quantity of blood which paſſes by, a part of the *Chylus* is mixed after this manner, and as it were in no remarkable proportion, that doth (as *Ariſtotle* ſays) more eaſily come to paſs; as when one drop of water is put into a Hogſhead of wine, or on the contrary, the whole is not mixed, but it is either wine or water; ſo in the *Meſſeraick veins*, being diſſected, there is found a *Chylus*, not the *Chylus* and blood a part, but mixed, and the ſame both in colour and conſiſtence to the ſenſe, as appears in the reſt of the *veins*; in which notwithſtanding, becauſe there is ſomething of the *Chylus* inconcocted, although inſenſible, Nature hath placed the *liver*, in the *Meanders* or crooks of which it is delayed, and receives a fuller tranſmutation,

tion; leaſt coming too ſoon raw to the *heart*, it ſhould overwhelm the beginning of life. Hence in *Embryons* there is no uſe of the *liver* where the *Umbilical vein* doth apparently paſſe through the whole, for there ſtands out of the *porta* of the *liver* a *hole* or *Anaſtomoſis*, that the blood returning from the *inteſtins* of the birth, paſſing not through the *liver*, but the forementioned *Umbilical vein*, might go to the *heart*, together with the mothers blood returning from the *Placenta* of the womb; from whence likewiſe, in the firſt forming, of the birth, it comes to paſſe, that the *liver* is made laſt. We likewiſe in a womans untimely birth, have obſerved all the members ſhaped, the *Genitals* diſtinctly, and yet ſcarce any foundation of the *liver* to have been laid. And truly ſo long as the members (as likewiſe the *heart* it ſelf in the beginning) are all whole, and that there is no redneſſe conteined in the *veins*, you ſhall ſee nothing but a rude collection as it were of blood, without the veſſels, inſtead of the *liver*, which you would think to be ſome bruſe or broken *veins*.

There are in an *Egg* as it were two *Umbilical* veſſels, one paſſing through the whole *liver*, from the *white*, and going directly to the *heart*; the other going from the *yolk*, and ending in the *vena porta*. For ſo it is, that a *Chick* is firſt only nouriſhed and found by the *white*, and afterwards by the *yolk*, after its perfection and excluſion; for the *yolk* may be found to be conteined in the belly of the *Chick* many dayes after the hatching, and it is anſwerable

rable to the nouriſhing of milk in other creatures. But we ſhall ſpeak of theſe things more conveniently in our obſervations concerning the forming of *births*, where there may be many enquiries of this nature, why this is firſt made and perfected, and that afterwards; and of the principality of Members, what part is the cauſe of another; and many things likewiſe concerning the *heart*, As why (as *Ariſt. de part. Anim.* 3.) it was made the firſt conſiſtent, and ſeems to have in it life, motition, and ſenſe, before any thing of the reſt of the body be perfected: And likewiſe of the blood, why before all things, and how it has in it the beginning of life, and of the creature; why it requires to be moved and driven up and down; and then for what cauſe the *heart* ſeems to have been made.

After the ſame manner in the ſpeculation of pulſes, to wit, why ſuch are deadly, others not; and in all kinds by contemplation of their Cauſes and Preſages, what thoſe ſignifie, and what theſe, and why.

Likewiſe in the *criſiſes* and *expurgations* of Nature; in nutrition, eſpecially in diſtribution of the nutriment; and likewiſe in all fluxions, &c.

Laſtly, in all parts of *Phyſick*, *Phyſiological*, *Pathological*, *Semeiotick*, *Therapeutick*, when I do conſider with my ſelf how many queſtions may be determined, this truth and light being given; how many doubts may be ſolved, how many obſcure things made clear,

I find a moſt large field, where I might run out ſo far, and enlarge my ſelf ſo much, that it would not only ſwell into a great Volume, which is not my intention, but even my life-time would be too ſhort to make an end of it.

Therefore in this place; that is to ſay, in the following Chapter, I ſhall onely endeavour to refer thoſe things to their proper uſes, and cauſes, which do appear in the Adminiſtration of *Anatomie*, about the *fabrick* of the *heart*, and *arteries*: for there where I intend to addreſs my ſelf, very many things are found which receive light from this truth, and do in return make it more clear, which I deſire to adorn, and confirm by *Anatomical* arguments, beyond all the reſt.

There is one thing, which although it ought to have place too in our obſervations concerning the uſe of the *Milt*, yet will it not be impertinent to take notice of it here by the by.

From the *ſplenick veins* drawn down into the *Pancreas*, there ariſe *veins* from the upper part of it: the *Coronal*, *Poſtick*, *Gaſtrick*, and *Gaſtræpiploick*; all of which, with very many branches and tendons, are diſperſed into the *ventricle*, as the *meſeraicks* are into the *inteſtines*: Likewiſe from the inferior part of this *ſplenick*, down as far as the *Colon* and *Longanon*, the *Hæmorrhoidal vein* is deducted. The blood returning through thoſe *veins* by both wayes, and carrying the raweſt juice with it (hence from the *ventricle*, that which is wateriſh and thin,

thin, the chilification being not as yet perfected; from thence that which is groſs and terreſtrial) in this branch of the *ſplenick*, by the permixtion of contraries, it is conveniently tempered; and Nature mixing thoſe two juices of more difficult concoction, by reaſon of their contrary indiſpoſitions, with great abundance of warm blood, which (by reaſon of the abundance of *arteries*) flows abundantly from the *milt*, it brings them, being now better prepared, to the *porta* of the *liver*, and ſupplies and recompences the defect of both by ſuch a ſtructure of the *veins*.

Chap.

CHAP. XVII.

The motion and circulation of the blood is confirmed by those things which appear in the heart, and from those things which appear in Anatomical dissection.

I Do not find the *heart* in all creatures to be a distinct and separate part; for some, as you would say *Plant-animals*, have no *heart*; Colder creatures of a softer make, and of a kind of similary constitution, such as are *Palmer-worms*, and *Snails*, and very many things which are ingendered of putrefaction, and keep not a *species*, have no *heart*, as needing no impulsor to drive the nutriment into the *extremities*: For they have a body *connate* and of one piece, and indistinct without members; so that by the contraction and returning of their whole body, they take in, expell, move and remove the nourishment, being called *Plant-animals*; such as are *Oysters*, *Muscles*, *Sponges*, and all sorts of *Zoophyts*, have no *heart*; for instead thereof they use their whole body, and this whole creature is as a *heart*.

In very many, and almost all kinds of Insects, by reason of the smallness of their Corpulency, we cannot rightly discern; yet in *Bees*, *flies* and *wasps* we may by the help of a perspective glass. You may likewise see something beat in *lice*, in which moreover you may clearly see the passage

of

of the nouriſhment through the *inteſtines* (this Animal being tranſparent) like a black ſpot, by help of this multiplying glaſs. But in thoſe that have no blood and are colder, as in *Snails*, *Shel-fiſh*, *Cruſted-Shrimps*, and the like, there is a little part which beats (like a *little bladder*, or an *ear*) without a *heart*, making its contraction and pulſe ſeldomer, and ſuch a one as you cannot diſcern but in ſummer, or in a hot ſeaſon.

In theſe creatures this particle is ordained too, that there is a neceſſity of ſome impulſion for the diſtribution of the nouriſhment, by reaſon of the variety of the *organick* parts, or the thickneſs of their ſubſtance: but the pulſations are made ſeldomer, ſometimes not at all, by reaſon of their coldneſſes, as it is meeteſt for them, being of a doubtful nature, ſo that ſometimes they ſeem to live, ſometimes to dye, and ſometimes to live the life of an *animal*, ſometimes the life of a *Plant*.

This is likewiſe contingent to thoſe Inſects which do lurk in the Winter, and are hid as if they were dead, and do only lead the life of a *Plant*; but whether this do likewiſe happen to ſome creatures that have blood, as to *Frogs*, *Snails*, *Serpents*, *Swallows*, we may not without reaſon make a queſtion.

In creatures which are a little bigger, and hotter, as having blood in them, there is an impulſion of the nutriment required, and ſuch a one perchance as is endued with more force; therefore in *Fiſhes*, *Serpents*, *Snakes*, *Snails*, *Frogs*, and others of the like nature, there is both one *ear*, and one *ventricle* of the *heart* allotted, whence riſes that moſt true Axiom of *Ariſt. de part. Anim.* 3. That no creature

ture having blood does want a *heart*, by the impulsion of which it is made ſtronger and more robuſt, and the nutriment is not only ſtirred up and down by the *ear*, but likewiſe is thruſt out further and more ſwiftly.

That in creatures yet greater, hotter, and more perfect, (as abounding with a great deal of hotter blood, and full of ſpirit) there is a ſtronger and more fleſhie *heart* required, that the more ſtrongly, more ſwiftly, or with greater force the nutriment may be thruſt out, by reaſon of the bigneſs of the body, and thickneſs of the habit.

And moreover, becauſe that more perfect creatures need more perfect aliment, and a more abundant native heat, that the nutriment of them may be concocted, and acquire a further perfection, it was fit that theſe creatures ſhould have *lungs*, and another *ventricle*, which ſhould drive the nutriment through them.

So in whatſoever creature there is *lungs*, there is likewiſe in them *two ventricles* of the *heart*, the *right*, and the *left*, and whereſoever the *right ear* is in any, there is the *left*, not on the contrary, that where the *left* is, there is the *right* one too; that I call the *left ventricle* which is diſtinguiſhed in place, but not in uſe from the tother, which doth diffuſe the blood into the whole body, not into the *lungs* alone, hence the *left ventricle* ſeems to make up the *heart* of it ſelf, being placed in the middle, and ſo fenced with higher ditches, and framed with greater diligence, that the *heart* ſeems to have been made for the *left ventricle's* ſake, and the *right ventricle* ſeems as it were a ſervant to the *left*, and does not reach to the

top

top of it, and is made up of a thinner threefold wall, and it has, as *Ariſtotle* ſays, a kind of articulation above the *left*, and is more capacious, as adminiſtring not only matter to the *left*, but giving nouriſhment likewiſe to the *lungs*.

But it is to be obſerved in *Embryons* theſe are far otherwiſe, and that there is no ſuch great difference of the *ventricles*, but like two kernels in a nut they are almoſt equal, the corner of the right reaches the top of the left, ſo that in them the *heart* hath as it were a double top at the point. Theſe things come to paſs becauſe in them whilſt the blood does not paſs through the *lungs*, as it does paſs from the *right boſome* of the *heart* to the *left*, both the *ventricles* do perform alike the office, bringing the blood through from the *vena cava* into the *arteria magna* by that oval hole and arterious paſſage, as hath been ſaid, and do equally divide it into the whole body, whence proceeds an equal conſtitution. But when it is time that the *lungs* ſhould be uſed, and the foreſaid unions begin to be ſtop'd, then does this difference of *ventricles* begin to be in their ſtrength, as likewiſe in the reſt, becauſe the *right* drives only through the *lungs*, the left through the whole body.

There are beſides theſe in the *heart* alſo *tendons*, as I may ſo ſay, or fleſhie twigs, and very many *fibrous connexions*, which *Ariſt.* in his book *de reſpir.* and *de part. anim.* 3. calls *nerves*, of which ſome apart are ſtretched with divers motions, and are partly hidden in furrows with deep ditches about them in the walls and *mediaſtin*, and they are like a kind of little *muſcles* which are underordained,

dained, and superadded to the *heart*, as auxiliaries, for the further expulsion of blood, that like the diligent and artificial provision of tackling in a Ship, they might help the *heart* contracting it self every way, and might squeeze out the blood more fully and forcibly out of the *ventricles*.

And this is manifest from hence, because some *animals* have them, some not, and all which have them are stronger in the *left ventricle* than in the *right*; some *animals* have them in the *left*, and not at all in the right, in men there are more of them in the *left* than in the *right*, and more in the *ventricles* than in the *ears*, and in some *ears* almost none; there are more of them in brawnie, musculous and rural bodies, and such as are of rougher habit of body, than in those which are tender, and in Women there are fewer.

In those creatures in which the *ventricles* within are smooth, altogether without *fibers* and *tendons*, and which are not cleft into ditches (as almost in all little birds, *Serpents*, *Frogs*, *Snails*, and the like, in the *Partridge* likewise and the *Hen*, and the greatest part of Fishes) in them neither those *nerves* or *fibers* mentioned, nor the *three-fork'd portals* are to be found in the *ventricles*. In some *animals* the *right ventricle* is smooth within, the *left* has those *fibrous* connexions, as in the *Goose*, *Swan*, and greater birds: In them the same cause is alledged as in all, seeing their *lungs* are spongious and soft they need no such force to impell the blood through them; therefore in the *right ventricle* either they have no *fibers*, or else fewer and weaker; nor are so fleshy and comparable to

Muſcles, but in the *left* they are ſtronger and more in number, more fleſhy and muſculous, becauſe the *left ventricle* hath need of more ſtrength and force, by reaſon that it ought to purſue the blood farther through the whole body.

From hence it is likewiſe, that the *left ventricle* poſſeſſes the middle of the *heart*, and hath a wall threefold thicker, and is ſtronger than the *right ventricle*. Hence all creatures, men likewiſe, by how much the habit of their fleſh is harder and more ſolid, and by how much more their outward members are more fleſhy, and fartheſt from the *heart*, and brawnie, ſo much more *fibrous*, thick, robuſt, and muſculous a *heart* have they; and this is neceſſary and clean on the contrary, by how much the more they are fine-ſpun, of a ſofter habit, and of ſlenderer bodies, ſo much the ſofter, flagging, and leſs *fibrous heart* within (or not at all) have they.

Likewiſe conſider the uſe of the *portals*, which were made for that cauſe, leſt the blood once let out ſhould be returned to the *heart*, and as well in the *orifice* of the *arterie*, as of a *vein*, they are up-lifted, and enterchangeably joining, they make a three ſquare line, ſuch as is imprinted by the biting of a *Swallow*, that being ſhut more cloſely they may hinder the reflux of blood.

There are three forked *portals* in the entry of the *vena cava*, and *arteria venoſa*, leſt that when the blood is moſt driven out it ſhould fall back, and for that cauſe they are not in all creatures, and in thoſe in which they are, they do not ſeem to be made by the ſame

di-

diligence of Nature, but in ſome they are ſhut more exactly, in others more careleſly and negligently; therefore in the *left ventricle*, that for the greater impulſion there may be a cloſer ſtoppage, there are only two like a Mitre, having *tendons* reaching out far, even to the *cones* of it, through its middle, that they may be moſt exactly ſhut. This perchance deceiv'd *Ariſtotle*, in making him believe that this *ventricle* was double, the diviſion being made athwart; leſt the blood ſhould fall back again into the *arterie*, and by that means the ſtrength of the *left ventricle* in driving forth the blood into the whole body ſhould be deſtroyed, therefore theſe *portals* do much ſurpaſs in bigneſs, ſtrength, and exact ſhutting, thoſe which are placed in the *right*. Hence likewiſe of neceſſity, no *heart* is ſeen without a *ventricle*, ſince it ought to be the well-ſpring, fountain, and cellar of blood. The ſame does not always happen in the *brain*; for almoſt all ſorts of birds have no *ventricle* in the *brain*, as it appears in the *Gooſe* and *Swan*, the *brains* of theſe, although the *brains* of a *Conie* be almoſt as big, yet the *Conie* hath *ventricles* in the *brain*, the *Gooſe* has not.

Likewiſe, wherever there is one *ventricle*, there hangs by it an *ear* flagging, cuticular, hollow within, full of blood; where there are two *ventricles*, there are likewiſe two *ears*; on the contrary, there is only one *ear* in ſome creatures, or at leaſt a *bladder* anſwerable to an *ear*, or the *vein* it ſelf dilated (but not the *ventricle* of the heart) making a pulſe inſtead of the

heart, as it appears in *Hornets*, *Bees*, and other Insects, whom I believe I can demonstrate by some experiments, to have not only a pulse but a respiration likewise in that place which they call the tail; whence it happens that it is lengthened and contracted, sometimes oftner, sometimes more seldome, according as they seem more panting or to be more indigent of air; but of this in the treatise of Respiration. It is likewise manifest that the *ears* do beat and contract themselves, as I said before, and cast the blood into the *ventricle*, whence it is that wheresoever there is a *ventricle* there an *ear* is requir'd, not only (as is commonly believed) that it may be the receptacle and cellar of blood, (for what needs there any pulsation for the retaining of it?) but the first movers of the blood are the *ears*, especially the *right*, being the first thing that lives, and the last that dies, as before is said; for which cause they are necessary, that they may serve to pour the blood into the *ventricle*. But the *ventricle* immediately contracting it self, doth more conveniently squeeze out; and more violently thrust forth the blood, being already in motion; as when you play at ball, you can strike it farther, and more strongly, taking it *a la vole*, than you could only throwing it out of your hand. But likewise, contrary to the vulgar opinion, because neither the *heart*, nor any thing else can so extend it self as that it can attract any thing in its diastole (unless in its return to its former constitution, being before squeezed like a spunge,) but it is certain, that all local motion comes first, and did take its beginning, from the contraction

of

of some particle; therefore by the contraction of the *ears*, the blood is cast into the *ventricles* as I open'd before, and by the contraction of the *ventricles*, it's thrown farther and removed.

Which truth concerning local motion, and that the immediate *motive organ* (in all creatures in which a motive spirit is primarily) is contractable, as *Arist.* sayes in his book *de spirat.* and elsewhere, and that *Aristotle* did know the *muscles* when he did refer all the pains and motion in creatures to the *nerves*, or that which is contractable, and therefore call'd those *tendons* in the *heart*, *nerves*; I hope it shall be made clear if at any time I shall have liberty to demonstrate concerning the *motive organs* of creatures, and the fabrick of the *muscles*, from my own observations.

But pursuing our purpose concerning the use of the *ears*, which we did demonstrate was to fill the *ventricles* with blood, we see it comes to pass, that the thicker and more compact the *heart* is, and of a grosser wall, the more *nervous* and *musculous* the *ears* are to draw in and fill it; and in those in whom they are contrarywise, it does appear in them as a bladder of blood, or a membrane conteining blood, as in fishes, for there the bladder which is in lieu of the *ear* is very thin, and so large that the *heart* seems to swim above it; but in those fishes in which this bladder is a little more fleshie, it seems very precisely to emulate and counterfeit the *lungs*, as in the *Barbell*, *Tench*, and others. *Caipe*

In some men, to wit such as are brawnie, and of a rougher habit of body, I have found the *right ear* so strong and so neatly made up within, with

the various contexture of *fibers*, that it did seem to be equal in ſtrength to the *ventricles* of other men; and truly I did wonder that in divers men there ſhould be ſuch difference. But it is to be obſerved, that in the birth, the *ears* are far greater than they are in it proportionated, becauſe before the *heart* is made, that it may do its own function, (as before was ſhewed) they do the office of the *heart*.

But the things that I obſerv'd concerning the forming of the birth which I made mention of before, and *Ariſtotle* confirms in an *egg*, do add a great deal of credit and light to the buſineſs at firſt, whilſt the birth is as it were a tender worm and whilſt it is yet (as is uſually) ſpoken in the milk, there is in it a little *bladder* or *bag* which beats, and as it were a portion of the *umbilical vein*; afterwards, when the birth being shaped, begins to have a ſtronger corpulency, this little *bag* becomming more fleſhy and robuſt (changing its conſtitution) turns into *ears*, above which the body of the *heart* begins to ſpring, as yet executing no publick office; but the birth, when 'tis already form'd, and that the bones are diſtinct from the fleſh, and it is a perfect creature, and that it is felt to have motion, then the *heart* is both found beating within, and does transfuſe the blood as I have ſaid out of the *vena* into the *arterie* through both the *ventricles*.

So Nature being perfect and divine, and making nothing in vain, neither gave a *heart* to any where there was no need, nor made it before there was any uſe for it, but by the ſame degrees in the form-

forming of all *animals* passing through the constitutions of all creatures (as I may say in the *egg*, *Worm*, and birth) it acquires its perfection in them all. These things shall be confirmed elsewhere by many observations in the forming of the birth.

Lastly, *Hippoc.* in his Book *de Cord.* did not without reason call it a *muscle*, seeing the action and function of both is the same, *viz.* to contract it self, and move somewhat else, that is, the blood.

Moreover, from the constitution of the *fibers*, and their motive frame, as likewise in the *muscles*, we may see the action and use of the heart. All Anatomists have observ'd with *Galen*, that the body of the *heart* is made with several draughts of *fibers* streight, thwart, and crooked, but in a *heart*, being boyl'd the structure of the *fibers* is found to be otherwayes.

For all the *fibers* in the walls and in the incloſure are circular, as they are in a *Sphincter*, but those which are in the *tendons* stretched out in length, are crooked; so it comes to pass that when all the *fibers* are contracted, it happens that the top is brought to the bottom by the *tendons*, and the walls are incloſed in a round, and the *heart* is contracted every way, and the *ventricles* strengthned. Wherefore since the action of it is contraction, we must needs imagin that the function of it is to thrust blood out into the *arteries*.

Nor must we disagree from *Aristotle* concerning the principality of the *heart*, and that it does not receive motion and sense from the *brain*, nor

blood from the *liver*, but that is the beginning of the *veins*, and of the blood, and the like; Seeing those that endeavour to confute him omit that chief argument, to wit, That the *heart* is the first subsistent, and that it hath blood, life, sense and motion before the *brain* or *liver* were made, or appear'd distinctly, at least before they could perform any function. To this add, That the *heart*, as a certain internal *animal* consists longer, as if Nature by the making of this first, would have the whole *animal* afterwards to be made, nourish'd preserv'd, perfected by it, as its own work and dwelling place. The *heart* is as it were a Prince in the Commonwealth, in whose person is the first and highest government every where; from which as from the original and foundation, all power in the *animal* is deriv'd, and doth depend.

But besides very many things about the *arteries* do likewise evidence and confirm this truth; when it is consider'd why the *arteria venosa* does not beat since it is numbred amongst the *arteries*; or why there is a pulse found in *vena arteriosa*, since the pulse of the *arteries* arises from the impulsion of blood; or that the *arteries* in the thickness of their *tunicles*, and the strength of them, do differ so much from the *veins*, because they bear the force of the impulsion of the *heart*, and breaking out of the blood.

Hence, since Nature who is perfect, makes nothing in vain, and is sufficient in all things, the nearer the *arteries* are to the *heart*, the more they differ from the *veins* in their constitution, and are more robust and full of ligaments, but in the furthest dispersions of them, in the *hand*, *foot*, *brain*, *mesenterie*

meſenterie, and *ſpermatick veſſels*, they are ſo like in their conſtitution, that earneſtly viewing their *tunicles*, it is a hard buſineſs to know one from the other.

And this is ſo for juſt cauſes. For the further the *arteries* are diſtant from the *heart*, by ſo much leſs ſtrength a great deal are they ſtruck, the ſtroak of the *heart* being weakned by the great diſtance. Add to this, that the impulſion of the *heart*, ſince it muſt needs be ſufficient in all the trunks and branches of the *arteries*, it is leſſened at every partition, as being divided, inſomuch that the laſt diviſions of the *capillares arterioſæ* ſeem to be *veins*, not only in conſtitution, but likewiſe in function, or do not give a ſenſible pulſe, or none at all, or elſe not alwayes, unleſs the *heart* do beat more forcibly, or ſome little *arterie* be dilated, or more open in ſome part. Hence it comes, that ſometimes we may find a pulſe in the teeth, ſometimes in the gums, and ſometimes we cannot. From hence I did certainly obſerve, that Boys whoſe pulſes are alwayes ſwift and frequent were in an undoubted Feaver, by this one token; as likewiſe in tender and delicate people by griping of their fingers, I could eaſily perceive by the pulſe of their fingers when the Feaver was in its ſtrength.

On the other ſide, when the *heart* beats faintly, not only not in the fingers, but neither in the wriſt, nor in the temples can any pulſe be felt, as in fainting, hyſterical ſymptoms, defect of pulſe, weak people, and thoſe that are departing.

Here Chirurgions are to be admoniſhed, leſt they be deceived; becauſe in the cutting off of members, the cutting away of fleſhy tumors, and

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in wounds, the blood does indeed come forcibly out of the *arterie*, but not alwaies with leaping, and that the ſmall *arteries* do not beat, eſpecially if they be tyed with a *ligature*. Beſide, that the *vena arterioſa* hath not only the conſtitution and *tunicle* of an *arterie*, but that it does not differ ſo much in the thickneſs of the *tunicle* from the *veins* as the *aorta*. The reaſon is, becauſe the *aorta* abides a greater impulſion of the blood from the *left ventricle*, than that does from the *right*; therefore it has the conſtitution of the *tunicles* ſo much the ſofter than the *aorta*, by how much the *right ventricle* of the *heart* is weaker than the left: And by how much the contexture and ſoftneſs of the *lungs* does abate from the habit of the body and fleſh, ſo much does the *tunicles* of the *vena arterioſa* differ from that of the *aorta*.

All theſe things do conſtantly keep proportion in men, for the more brawny, muſculous, and of harder habit of body they are, and the ſtronger, thicker, and more fibrous heart they have, ſo much the more anſwerable *ears* and *arteries* proportionably they have in thickneſs and in ſtrength. Hence in thoſe creatures, the *ventricles* of whoſe *hearts* are ſmooth within, without roughneſs, *portals*, and with a thinner wall, as in *Fiſhes*, *Birds*, *Serpents*, and very many ſorts of creatures, in them the *arteries* differ very little or nothing from the thickneſs of the *veins*.

Beſides, the *lungs* have ſuch large veſſels, their *vein* and *arterie*, that the trunk of the *arteria venoſa* does exceed both the *crural* and *jugular* branches, and are ſo full of blood, as by experience and my own eye-ſight (nor was I deceived in the inſpecti-

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on of those things which I saw in dissected creatures) that upon the wounding of them, all the whole blood has run out; the cause, by reason that in the *lungs* and in the *heart* is the fountain, cellar, and treasure of blood, and store-house of its perfection.

Likewise we see in Anatomical dissection, that the *left ventricle* and the *arteria venosa* does abound with so great a quantity of blood, and indeed of the same colour and consistence with that with which the *right ventricle* and the *vena arteriosa* is filled, alike black and clotted, because the blood passes hither from thence continually through the *lungs*.

Lastly, the *vein* called *arteriosa*, commonly has the constitution of an *arterie*, the *arteria venosa* of a *vein*, because in truth, both in function, constitution, and all things else, that is an *arterie*, and this a *vein*, otherwise than is commonly believed; besides, the *vena arteriosa* hath such a wide *orifice*, because it carries a great deal more blood than is necessary, for nourishing of the *lungs*.

All these *Phænomena's* to be observed in dissection, and very many more, if they be rightly weighed, seem to clear the forefaid truth abundantly, and indeed to confirm it, and withall to go against the common opinion: Seeing it is very hard for any to demonstrate by any other way than we have done, for what cause all these things are appointed.

FINIS.